ASSESSING THE CONSERVATION VALUE OF WETLANDS AND WATERBIRDS WITH A FOCUS ON THE WINTER RAINFALL REGION OF SOUTH AFRICA

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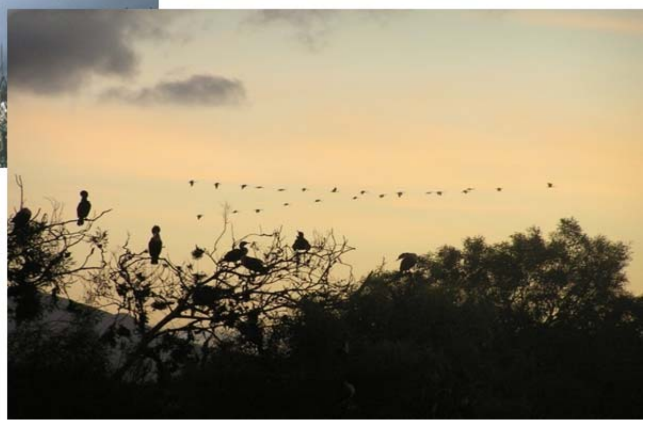
Animal Demography Unit

"Waterbirds tell many stories
about the biological richness of our planet.
They also provide our best tales
of regional and global connectedness.
By their individual movements and the variable fates
of their populations in response,
to increases or decreases in suitable habitat,
our waterbirds and waders provide connections,
between countries,
between different levels of administration and management,
between investigators,
between people"

Theunis Piersma
Shorebird Researcher
University of Groningen
The Netherlands

Foreword to 'Numbers and distribution of wintering waterbirds in the Western Palearctic and Southwest Asia in 1997, 1998 and 1999', Wetlands International, Wageningen



Declaration

I hereby declare that all of the work presented in this thesis, titled "Assessing the conservation value of wetlands and waterbirds with a focus on the winter rainfall region of South Africa", is my own, except where otherwise stated in the text. This thesis has not been submitted in whole or part for a degree at any other university.

Signed in Cape Town in May 2012

Signed by candidate

Douglas Michael Harebottle

This thesis is dedicated to:

my wife, Samantha, who continually believed in me and supported me throughout many long and sleepless nights. I am extremely grateful for her love and companionship during this time and for simultaneously keeping a family household going.

and Michael and Regan who patiently endured their father working late nights, odd hours and weekends. May this inspire them to reach great heights in their chosen career paths.

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Assessing the conservation value of wetlands and waterbirds with a focus on the winter rainfall region of South Africa

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Abstract

This thesis deals with the development and application of a new tool to assess the conservation significance of wetland avifauna. Termed the Waterbird Conservation Value (WCV) score, this method sums the proportion of each species' count relative to the global 1% threshold level for each species; the value obtained measures the overall conservation importance of the wetland to waterbirds. The score is evaluated at flyway level (East-Atlantic flyway) and then applied at regional and local scales. The regional and local analyses focused on various long-term waterbird monitoring datasets in the winter-rainfall region of South Africa. The primary aim was to assess the conservation significance of selected wetlands in the region based on abundance, seasonality and trend data. The selected sites were representative of different wetland types, inundation patterns and geographical location.

The results revealed that the WCV score is a useful tool to assess the conservation value for wetland avifauna and compliments the Ramsar 1% criterion, on which it is based. It allows for all species at a site to make a contribution to the conservation value of a site and is not restricted solely to species meeting the 1% criterion. There is a strong, but not overwhelming relationship between large WCV scores and the number of 1% threshold species. However, large values for the WCV scores may be obtained either by small contributions from a many species or large contributions from a few species. The major contributing factor to the score is the proportion of the 'count' estimate to a species' 1% threshold value. Ongoing assessment and re-evaluation of waterbird population estimates is therefore critical to the WCV score as 1% thresholds are derived from these estimates.

The use of visual analytics to display outputs of these data demonstrated at a regional scale the effectiveness of colour-coded histograms and radar plots to interpret WCV scores. These graphical outputs assist in easily setting conservation priorities at multiple sites or at the larger landscape level. At a site level, the WCV score was used to specifically address the issue of changing waterbird composition during shifts in the hydrological state of the Bot River estuary; this new and innovative approach added value to the standard approaches of assessing survey data of wetland birds.

I used correspondence analysis and estimated Daily Energy Intake (DEI) to determine waterbird relationships and ecological impact at 30 wetlands in the Western Cape. The WCV score was applied across all sites determine conservation importance. There were strong waterbird-wetland associations between saline wetlands (estuaries and estuarine bays) and freshwater wetlands (lakes and waste water treatment works). Palearctic migrants were strongly associated with coastal sites while residents showed strong links with freshwater sites and/or brackish wetlands. Biomass and DEI values varied seasonally for most wetlands which highlighted the importance of species using different sites at different times of the year. Site conservation status did not show strong associations with any waterbird groups. Overall, three sites, Strandfontein Waste Water Treatment Works, Langebaan Lagoon and Berg River Estuary were the most important sites in terms of numbers of birds, waterbird conservation value score and energy consumption. They contributed 49.7 % to the conservation value of all sites in the Western Cape and are critical localities for waterbird conservation in the region.

In terms of the future of waterbird conservation in the winter rainfall region and the Western Cape, I discuss the use of holistic, integrated and landscape approaches to better understand how waterbirds utilise the network of wetlands in the region. The WCV score is discussed as a useful biodiversity conservation tool which can rapidly assess conservation importance of wetlands. I suggest that it should be incorporated within existing national and global waterbird monitoring programmes as a way to monitor and assess wetland importance and species significance on an ongoing basis. Finally, proposals and recommendations on how to improve research outputs arising from waterbird survey data are made.

Layout and contributions

This thesis consists of six main chapters and four appendices. The chapters and the appendices were written as papers for submission to journals. Consequently, some repetition of methods and references was unavoidable; where applicable I describe a method in a chapter and referred to this elsewhere in the thesis. Tables, figures and appendices follow the text for each chapter; references for each chapter are given at the end of the chapter.

Data for some of the site accounts were compiled by various staff members of Cape Nature (then Cape Nature Conservation) and many public volunteers. Without their dedication and commitment this regional review of waterbirds would not have been possible; their vital roles will be acknowledged in co-authorships of the forthcoming series of papers. I was responsible for the collation, analysis and writing of each chapter. Fundamental ideas were discussed with my supervisors, Prof. L.G. Underhill and Dr A.J. Williams, and with Dr Rene Navarro a fellow work colleague. They advised on methods of data analysis, assisted with the wording of some methods and commented on chapter drafts. L.G. Underhill developed additional statistical programs to analyse data for Chapters 4 and 5.

A version of Appendix A was published in *Ostrich (African Journal of African Ornithology)*, 2008, 79: 147–163.

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I am indebted to Prof. Les Underhill, my supervisor and boss for allowing me the opportunity to pursue this PhD. At the outset we had numerous discussions about the topic for my thesis, but thanks to his foresight and knowledge we eventually agreed upon using the ADU and CapeNature waterbird datasets. This was ideal, since soon after I had arrived at the ADU and started working on the CWAC (Coordinated Waterbird Counts) programme I had developed a keen interest in waterbirds and soon discovered that not much is known about the ecology of many of the species in South Africa. This then provided a perfect platform from which to launch my PhD and I owe a great sense of gratitude to Les for spurring me on to undertake this task. His guidance, patience and statistical insights have been inspirational throughout the duration of my PhD Trying to balance the needs of a full-time job, family commitments with a PhD has been the greatest challenge for me, and Les understood this and never pushed me too hard, although sometimes I probably needed a slight push or two. But we managed to work through this at a steady, consistent pace, and I shall never forget the many nights spent at his house, drinking copious amounts of coffee, chatting and working on completing analyses or putting the final touches to chapters. Les, you have not only given me the guidance necessary to complete this 'chapter' in my life, but have strengthened my capacity as a scientist, something which I hope to continue building on into the future.

To my co-supervisor Dr Anthony (Tony) J. Williams I owe a big thank you. Early on in my PhD we used to sit for a couple of hours a week in his office talking about specific chapters or just waterbirds in general. From these discussions, endless loose pieces of paper with numerous scribbles on them ended up in my possession from which I was meant to interpret later, and quite often I used to head back to Tony's office for a translation update. Nevertheless, these discussions, 'notes' and emails were extremely valuable and provided valuable input into my thesis. Thank you Tony! You so often helped me re-focus my attention on the more 'practical' aspects of waterbird ecology and often this was needed as I would often be aiming beyond the scope of the study or had misinterpreted some result or analysis. If there are two things that Tony has left me with it is that you can never have too many references and that it is all about the 'philosophy', and not so much about the actual results, provided the latter has been carried out correctly.

I am grateful to CapeNature, through Tony Williams, for access to some of the datasets used in the thesis. Numerous people, most now ex-employees of the organisation, diligently carried out surveys at Rocher Pan, De Hoop Vlei and Droëvlei since 1979. Although these surveys were intended to be reported on, only short summaries were published. I am therefore grateful that I could use these data to carry out more detailed analyses and to (eventually) get these results into the scientific domain. Principal staff who diligently coordinated counts at the above sites included: CW Heÿl, MH Currie, G Palmer, A Scott, M Scott and K Shaw. To Vince Ward, who previously worked for CapeNature, I owe a debt of gratitude for digitising the data from De Hoop Vlei (Appendix D). This was a laborious and mundane job but he managed to finish it speedily and efficiently. Cape Nature also provided some funding to reimburse volunteers for their travelling expenses to the Bot River estuary (Chapter 4) in order to carry out counts.

This thesis would not have been possible if it were not for the many CWAC volunteers who gave up (and still give up) their 'Saturday mornings' to spend a few hours counting waterbirds. To do this month after month, year after year takes enormous effort and dedication. I will be forever grateful for 'their man-hours', turning their observations into useful science and conservation outcomes.

In no particular order I would like to mention some of the volunteers who have contributed to some of the datasets here. A list of this nature is bound to miss some people for which I apologise.

Yvonne Weiss and Graham Tong were instrumental in setting up the Paarl Monitoring Group, a group which conducted (and is still conducting) counts at Paarl Waste Water Treatment Works (Appendix A) from 1994–2004. Other core members of the group who assisted Yvonne and Graham by diligently conducting counts were Ben Weighill, Sally Weighill, Jeanette Fisher, Louis Hugo, Keith Morgan, Jo Hobbs, Patrick Hurley, Pikkie Rousseau, Penny Lloyd and Rita Meyer. Many others assisted on one or more occasions. Cedric Morkel, Superintendent of the Paarl Waste Water Treatment Works, provided useful information on structural changes to the sewage works and data pertaining to water-level fluctuations, organised building and maintenance of the hides, and of the kingfisher bank. Yvonne and Graham helped supply additional information on the history of the sewage works.

Another person who I need to make special mention of is Mariana Delport, from the Tygerberg Bird Club. She has been coordinating waterbird counts at the Bot River Estuary (since 1993) and Droëvlei Dam (since 1995), and is still active in this role today. She was instrumental in coordinating and setting up the monthly counts programme at the Bot River Estuary so that 'we could see what happens to the birds after they opened the mouth'. It was an onerous task especially because there were no local skilled observers based near the estuary and volunteers had to be sourced from the Tygerberg, Cape Town, Hermanus and Kleinmond Bird Clubs. She managed to get people to count monthly for almost three years (an almost impossible feat) and this data formed the bulk of the data in Chapter 3. Her 'band of merry counters' consisted of Lesley Teare, Kevin Drummond-Hay, Rodney and Anke Gray, Penny Palmer, Joy Rüger, Helene Thompson, Ray Gordon, Ken Winterton, Alf Friend, Bernie Edgcumbe and Beverley Patterson; many other observers assisted on one or more occasions.

For Droëvlei Dam (Appendix B) stalwart observers included Bernie Edgcumbe, Jurie Fourie, Douw Steyn, Jim Eva, Helene Thompson, Bobby and her late husband Etienne de Villiers, Beverley Patterson, Gerald Wingate and John Fincham; some additional observers helped out occasionally. There is some considerable overlap in the two groups and I am grateful to these dedicated and committed birders/volunteers for making huge contributions to waterbird conservation efforts in the Western Cape.

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Illustrations used in chapter and appendices cover pages are taken from the Southern African Bird Atlas and used by permission of BirdLife South Africa. The contributing artists are as follows: S. MacLarty, Glossy Ibis (Chapter 1), P. Meakin, Curlew Sandpiper (Chapter 2), P. Meakin, Pied Avocet (Chapter 3), P. Noall, Red-knobbed Coot (Chapter 4), S. MacLarty, Yellow-billed Egret (Chapter 5), J. Rooke, Black-necked Grebe (Chapter 6), R. Denison, White-winged Tern (Appendix A), I. Jordaan, Egyptian Goose (Appendix B), P. Noall, Cape Shoveler (Appendix C) and J. Rooke, Yellow-billed Duck (Appendix D).

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To my parents, Mervyn and Patricia Harebottle, I owe so much. It has been a long road, dad and mom. From humble beginnings in the Kruger National Park to joining the Witwatersrand Bird Club as a junior member – I always knew, since my high-school days, what career path I wanted to follow. You humbly sacrificed for me to go to University and to leave with a M.Sc.in Zoology. I felt proud of my achievement and I know you were proud of me. This provided the perfect grounding and, although I probably should have followed through with a PhD then, life threw some curve balls and I got to do some 'other learning'. Well, here it is mom and dad, my dream that has come true. You guys have been so supportive and I really appreciate all that you have done for me over the years. Your constant love and guidance has been pivotal in my life. Thank you both. I love you both very much!

To my sons, Michael and Regan. What can I say? I hope that by seeing your father working aimlessly behind his computer night after night with papers and books surrounding the table and floors, it will inspire you to achieve great things in your life. Aim high, achieve your goals and most of all pursue your dreams, as I have mine. There is nothing better than having the personal satisfaction of seeing your hard work pay off. So, whatever your desires and passions are in life, know that I am right behind you in whatever you choose to do, as you have been behind me during the last number of years. We will now have more time to do the things that we have missed out on. I love you both very much.

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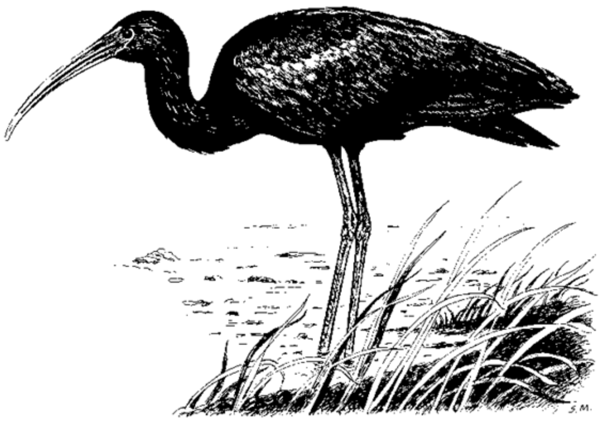
Chapter 1

Introduction and background



Introduction

Wetlands and wetland conservation in a global context

Wetlands cover 4–6% of the earth's surface and are considered to be one of the most productive ecosystems on earth's surface (WWF/IUCN 1988, Maltby 1991, Wetlands International Africa 2009). Globally many wetlands are under threat (Finlayson and Moser 1991, Cowan 1995, Davies and Day 1998, Terpstra 2003). In the USA it is estimated that more than 54% wetlands had been lost by the mid-1980s, primarily to agriculture and industrialization (Gibbs 2000). Foote et al. (1996) described how an increasing rural population in India places enormous pressure on natural wetlands and described 12 major causes of wetland loss in that country, agriculture again dominating as the primary cause. In south-western Australia, Davis and Froend (1999) found that 70% of the wetlands along the coastal margins had been lost to agriculture and urban development.

In South Africa, Kotze et al. (1995) and Breen and Begg (1989) surmised that similar trends as described above have occurred and that as much as half of all natural wetlands were lost in the 20th century, mainly to agriculture and urbanisation. At the same time, numerous artificial wetlands have been created: state impoundments, large numbers of farm dams, sewerage works in cities, towns and villages, "water features" in all manner of contexts (from shopping malls to golf courses) and sportsfields that flood seasonally (Taylor et al. 1999, Brown and Magoba 2009, Duckworth et al. 2012).

Natural wetlands provide important functions that are essential to the functioning of biotic communities and maintaining quality of the environment (Noble and Hemens 1978); these include *inter alia* shoreline stabilization, flood control, sediment and nutrient retention, and food chain support (Maltby 1991). Waterbirds, as top trophic organisms in wetlands, are intricately linked to these systems and are dependent on these systems for survival and in particular for the provision of food, nesting material, and breeding and roosting habitats (Dennis and Tarboton 1993). Generally wetlands are used by a host of different species which either exploit them throughout the year (resident species) or for only part of the year (migrant and nomadic species). Thus, wetland sites whether at a local scale or at a global or flyway scale form important habitat chains for waterbirds which are mobile and able to use a variety of different sites through the year. The amount of usage, and by how many species and individuals, can vary depending on environmental conditions. It is in this context that this thesis was developed.

Rationale for this thesis

Waterbirds are generally conspicuous; many are charismatic and others congregate in large numbers. This makes them readily countable and ideal candidates for long-term monitoring programmes. Gillisen et al. (2002) stated that *"no other group of birds have been so comprehensively and frequently surveyed"*. Their association with wetland ecosystems makes them good indicators for the condition of these environments. They are also valued by numerous stakeholders including local human populations, tourists and hunters (both sport and subsistence) (Gillisen et al. 2002). But ultimately wetlands play important ecological roles for waterbird populations whose survival and annual cycles (breeding, moult, migration, etc.) are dependent on these habitats.

Over the last 60–70 years in South Africa, waterbird studies, which have been based on survey data, have largely been either site-based or species-focused (see below). Notwithstanding the value of the outputs produced from these studies, they have limited conservation application for a group of species which are mobile and respond relatively quickly to changing seasonal and exceptional rainfall, dynamic habitat changes and hydrological regimes. Regional approaches to understanding the occurrence, abundance and conservation importance of the full suite of waterbirds have rarely been undertaken in southern Africa. Winterbottom (1960) conducted multiple vlei counts in the Cape Town area while Boshoff and Palmer (1991), Boshoff et al. (1991a, b, c) and Boshoff and Piper (1993) carried out an intensive study at the Wilderness-Sedgefield lakes; the latter study compared waterbirds across six waterbodies in an area encompassing about 100km^2 along the southern coast of the Western Cape. A larger spatial study was done in Botswana by Herremans (1999) who looked at waterbird densities and seasonality in the Kalahari Basin (c. 1 050 km^2).

Initially, the primary objective of this thesis was to explore patterns of waterbird abundance at major wetlands in the winter rainfall region of the Western Cape, and to assess their conservation importance. However, it soon became clear that the standard approach to wetland assessment, the time-honoured 1% threshold criterion of the Convention on Wetlands of International Importance (Ramsar Convention) (Wetlands International 2006) was not sensitive enough to describe the avifaunal value of wetlands. Thus a key thrust of the thesis became deflected into the development of a new approach to assess the importance of wetlands based on waterbird surveys. The effectiveness of this new tool is first demonstrated on a flyway scale, using data from Europe, western Africa and southern Africa. The thesis then returns to its original focus on the Western Cape's wetlands, and uses the new tool as part of the assessment of the conservation value of these wetlands, based on long-term waterbird surveys.

Scope and aims of this thesis

This thesis considers waterbirds and wetlands within the East-Atlantic flyway and in the winter rainfall region of the Western Cape Province, South Africa. Further details and reference to the East-Atlantic flyway is made in Chapter 2. The winter-rainfall region is described in more detail below, but in general waterbirds, and biotic communities, experience different annual climatic and environmental conditions here compared with the rest of South Africa which receives predominantly summer rainfall (Cowling et al. 1997, Schulze and Maharaj 2007).

Based on this the broad aims of this thesis were four-fold:

1) To introduce and describe a new and innovated method to assess the conservation value of wetlands based on waterbird survey data;
2) Application of the method to determine its effectiveness and value in evaluating waterbird conservation priorities at various spatial scales;
3) To analyse and critically assess long-term waterbird data at five representative wetland sites in the winter rainfall region through application of this new method and other assessment tools; and
4) To assess the outcomes of the site analyses in a regional context as a model for determining waterbird conservation priorities in the winter rainfall region; subsidiary aims here were to establish relationships and links amongst prominent wetlands in the Western Cape in order to try and determine how waterbirds use sites and what the critical wetlands are for waterbirds in the winter rainfall region.

Data for the analyses were drawn from three main sources: the International Waterbird Census (IWC) (Wetlands International 2006), Southern African Waterfowl Census (TB Oatley *in litt.*) and the Coordinated Waterbird Counts (CWAC) programme (Taylor et al. 1999). There was some overlap between the data sources and data were either used in isolation or, where applicable, combined between the two data sources to generate a longer time series.

From the results I attempt to draw conclusions and recommendations based on the following questions:

1) Is the new conservation value assessments a valuable and important conservation tool?

2) How important are data graphics and presentation in displaying an interpreting waterbird assessments?
3) Were the site analyses valuable, based on the quality and quantity of data used?
4) Can this regional approach discern linkages between the sites based on the data presented and provide conservation outputs?
5) How useful and practical are the Coordinated Waterbird Counts protocols in relation to other (e.g. are count times and frequency appropriate for long-term waterbird population monitoring, and if not, why not)?
6) What does the future hold for waterbird monitoring in the region?
7) What does this mean for waterbird conservation in the winter rainfall region and Western Cape Province?

Background

Climatic and wetland overview

In the context of this thesis, I discuss the climatic conditions present in South Africa. This is followed by a consideration of wetland regions and wetlands in the winter rainfall region.

South Africa's climate

Schulze et al. (2007) classified South Africa into 12 climatic zones using the Köppen classification system (Figure 1.1, Table 1.2). The system is based on rainfall magnitudes, rainfall seasonality and rainfall concentration, as well as durations above or below threshold temperatures on a monthly basis.

In terms of precipitation most of South Africa falls within the summer rainfall region (Figure 1.2) which is characterised by warm, wet summers and cold, dry winters. Mean annual rainfall for South Africa is about 500mm with the eastern regions being wetter (500–800 mm) than the western parts (< 300 mm) (Schulze 1997). The summer rainfall region largely constitutes the inland plateau occurring above the Escarpment (600–1 250 m.a.s.l.). Precipitation primarily occurs as thunderstorms, and winters usually contain frost and in higher lying regions snow is frequent. The region with year-round rainfall consists of narrow strip of coastal plain between Breede River Mouth and Port Elizabeth. Rainfall is fairly uniform throughout the year with the mean annual rainfall exceeding 1 000 mm.

The region of South Africa relevant to this thesis encompass three zones: a desert zone along the western coastal region, a Mediterranean zone along the western coastal region and a Mediterranean zone in the Cape Fold Mountains (Figure 1.3). All three regions have an overall strong dry and arid component to them; the Mediterranean zone is described below.

The winter rainfall region of South Africa

The southwestern part of South Africa constitutes the winter-rainfall region (Figure 1.2). It stretches from the Olifants River estuary on the Atlantic Ocean to the Breede River estuary on the Indian Ocean. Most rain falls between May and September, the austral winter months, with peak rainfall usually from June–August; the amount and intensity of rain varies spatially and temporarily (Schulze and Maharaj 2007). In the region to the north of the Olifants River mouth, in the Northern Cape Province, the landscape is arid with hot, dry summers, and warm winters with erratic rainfall; mean annual rainfall is less than 250 mm per annum (Schulze 1997). To the south of the Olifants River Mouth the region falls within the Western Cape Province, and is classified as having a Mediterranean climate. Here, summers are warm and dry with strong south-east prevailing winds (known locally as "The Cape Doctor") while in winter north-west winds bring the cold fronts and associated rain that falls as prolonged showers (Appendix 1.1). Mean annual rainfall is *c.* 400 mm per annum in this region but rainfall varies in the amount and intensity; more rain falls in the southwest and along the southern coastal sections than in the interior and along the west coast of the Western Cape. There is also a large variability in the timing of the start and end of the rainy season, and in the amount of rain that falls at a single locality. This region, due to its Mediterranean climate, is more commonly referred to as the winter rainfall region in South Africa and is the area of focus for this thesis, hereafter referred to as WRR.

The vegetation in the WRR is dominated by plants of both the Fynbos and Succulent Karoo Biomes. The fynbos is characterised by species belonging to the Proteaceae, Ericaceae and Restioaceae, while short karoo scrub vegetation dominates the succulent karoo landscape. The fynbos vegetation is well adapted to survive the dry, windy summer periods (Cowling et al. 1997).

Wetland regions of South Africa

Cowan (1995) classified four broad wetland regions in South Africa based on the general morphology of the country: plateau, mountains, coastal slopes and rimland, and coastal plain. These were further subdivided into sub-groups within each region based on geomorphology and climate. A total of 26 wetland regions was delineated (Figure 1.3).

Within the scope of this thesis, three of these wetland regions fall within the winter rainfall region: Western coastal slope – desert, Western coastal slope – Mediterranean and Cape Fold Mountains – Mediterranean (Figure 1.3). The first two regions form part of the coastal plain in the region and are divided into the drier, arid region in the north and the moister, semi-arid Mediterranean region in the south; the Cape Fold Mountains constitute the high-lying interior escarpment region.

Wetlands in the winter rainfall region

The WRR supports a variety of different wetland types. Natural wetlands include estuaries and estuarine bays, palustrine wetlands (marshes and vleis), lacustrine wetlands, rivers and seasonal pans; artificial sites incorporate impoundments, farm dams, waste water treatment works and commercial salt pans.

Historically, this region, and in particular the Cape metropolitan area, contained more natural wetlands than what is present today (Brown and Magoba 2009). Prior to colonization by Dutch settlers in the mid-1700s and later by the English in the early 1800s, the region's coastal plain had large floodplains and its associated marshes and vleis (freshwater lakes) were extensive, largely inter-linked and undisturbed (Stephens 1929, Southern Waters 2000). The Cape Flats, a flat coastal plain area stretching from the eastern slopes of Table Mountain 50km westwards to the Hottentots Holland Mountains, contained many large palustrine wetlands (Brown and Magoba 2009), but with the development of roads and settlements in the mid-1840s (Stephens 1929), most of these were drained and filled to make way for a growing human population and agriculture. Human activities and disturbance changed the size and shape of many of larger palustrine wetlands and rivers in the region, and in particular on the Cape Flats (Stephens 1929, Southern Waters 2000). The distribution and extent of present day wetlands in the region therefore represents the remnants of these larger wetlands and wetland systems. Historically, waterbird populations would have been far more abundant and widespread in the region when wetlands were more expansive and more permanent. Nowadays, due to the loss and degradation to wetlands over the past 300 years, waterbirds make use of a smaller 'pool' of natural, permanent wetlands and utilise more temporary and artificial wetlands (Brown and Magoba 2009).

Seasonally, most of the palustrine wetlands usually start to fill from about May onwards with the start of the winter rainfall; inundation is either directly from rainfall which raises the water-table or from inflow from the catchment via rivers and streams. After September when most of these wetlands have reached peak inundation; this also coincides with the start of summer when there is high plant and invertebrate productivity (Cowling et al. 1997). The extent of the annual level of peak inundation depends on the amount of rainfall during the preceding winter. Water-levels start to subside from about December when hot, dry and windy conditions prevail and lead to high evaporation levels (Schulze 1997). Some wetlands dry out completely from about January onwards; some only dry out in drought years. Dry conditions persist until April–May when the wetlands start to fill again with the onset of the first winter rains.

Permanent wetlands are not subject to the extent of seasonal change of ephemeral systems. This is particularly true of estuarine bays and permanently open estuaries which are influenced more from tidal exchange; estuaries have increased freshwater input during the rainy season. Sewage works, reservoirs and impoundments generally experience small fluctuations in water-levels during each wet-dry cycle each year; these fluctuations are usually small or negligible but can vary depending on the amount of rainfall and extent of the dry season period. Farm dams, are generally smaller waterbodies than state dams, and vary in their seasonal response to rainfall; however they are usually subject to greater fluctuations and often dry out towards the end of the dry season (Davies and Day 1998).

Inundation patterns of wetlands in the WRR are variable both spatially (between sites in different areas) and temporally (between years). Consequently, waterbirds are faced annually with varying conditions in different areas at different times of the year. This variation is based on factors affecting the hydrology at each site and include: location in the region, location in the catchment, rainfall, temperature, evaporation rates and wind strength (Davies and Day 1998, Roshier et al. 2002, Brown and Magoba 2009).

A brief overview of the history of waterbird counts and relevant previous studies

Waterbird monitoring – a global perspective

Ever since the time of the Egyptians, waterbirds have held fascination for man and can nearly always be traced back to hunting for food and sport (Kuijken 2006). It was not until the mid-1800s during the rise of the industrial revolution that conservation thinking developed around nature and wild animal populations. However, it was the development of large scale hunting of wildfowl in the early parts of the 20th century which placed growing pressure on wild populations and concerns were raised from naturalists. Through nature conservation organisations and ornithological societies, naturalists and ornithologists rallied to combat the decline in wild bird populations but notably wildfowl (Kuijken 2006). The International Committee for Bird Preservation (now BirdLife International), established in 1922, initiated an International Wildfowl

Inquiry in 1941. This probably represented the first coordinated effort to monitor wildfowl populations on a global scale.

In 1967, the International Waterfowl and Research Bureau (now Wetlands International), launched its International Waterbird Census through mid-winter (January, the southern hemisphere summer) censuses of waterfowl in Europe, and some countries in Asia and Africa. This has continued as a key activity of the organisation and today over 100 countries, from Africa, Asia, the Neotropics and North America participate in the counts and which now include all waterbirds (see definition below). The results of the International Waterbird Census have been used in the designation of nearly half of the 1 369 Wetlands of International Importance in 138 countries designated under the Ramsar Convention (http://www.wetlands.org).

Waterbird counts in South Africa and the Western Cape

Waterbird monitoring apparently started in South Africa in the late 1930s and early 1940s; Table 1.1 provides a chronological list of the major published surveys of wetlands in the winter rainfall region. The first was by Broekhuysen and Meikeljohn (1941) who reported on casual but regular observations of Palearctic migrant shorebirds at some local wetlands in the Greater Cape Town area. The Cape Bird Club was formed in 1948, in Cape Town, and many members participated in 'bird counts'. The 'Cape Bird Club vlei counts' were started in 1952 (Winterbottom 1960) and were possibly one of the first coordinated waterbird census projects to be undertaken, largely by volunteers, in the Western Cape, and possibly South Africa. Winterbottom (1960) reported results from these vlei counts and also made reference to unpublished studies carried out by Richard Liversidge on the Black River, Cape Town, prior to the start of the Cape Bird Club vlei counts in 1952. During this period bird monitoring was generally led and coordinated by ornithologists based at the University of Cape Town but were well supported by members of the Cape Bird Club.

In the 1950s, a few sites (e.g. Strandfontein Sewage Works and Rietvlei) started to be surveyed on a more regular basis (Blaker and Winterbottom 1968). From these surveys, Strandfontein Sewage Works emerged as a valuable site for waterbirds in the Western Cape. Monthly surveys, instigated in 1985, were still maintained by members of the Cape Bird Club in 2011; only a handful of surveys have not taken place (due to bad weather or lack of suitable manpower). This dataset represents one of the longest running surveys at a single site at this count frequency in South Africa, and at least in Africa. Kaletja-Summers et al. (2001a, b) analysed the Strandfontein and Rietvlei datasets in the early 2000s.

During the 1970s and 1980s bird club members also surveyed waterbirds (with annotated lists of terrestrial species) at a number of wetlands that were under threat from developments. Two of these included the construction of a residential marina at the Zandvlei River estuary and the construction of the Milnerton golf course next to the Diep River estuary; for the latter a 10-year dataset of almost monthly counts exists but remains unpublished (Animal Demography Unit unpubl. data). Table 1.1 highlights how the value of the surveys and integrity of the data improved through each decade since the Broekhuysen and Meikeljohn (1941) counts.

There are also examples of specific waterbird census programmes that have been set up since the 1950s in southern Africa and South Africa. The African Wildfowl Enquiry, launched in June 1954 (Anon. 1954), was intended to undertake a comprehensive investigation into the biology, behaviour and status of ducks and geese in the southern hemisphere of Africa. The enquiry was coordinated by the Southern African Ornithological Society (now BirdLife South Africa) and the Witwatersrand Bird Club. Winterbottom (1964) and Frost (1971, 1972) reported on some results, but this dataset remains largely unanalysed. The field cards are currently stored in the Animal Demography Unit, University of Cape Town and were in the process of being digitised in 2010 and 2011; these data will provide opportunities for long term analyses in the coming years (LG Underhill pers. comm.). It will provide an excellent baseline against which recent data can be compared to detect changes in distribution and abundance of species at a sub-regional level.

The South African Waterfowl Census was initiated in 1979 (TB Oatley *in litt.*) and, like the African Wildfowl Enquiry, focused on gathering information on waterfowl. However, the programme was confined to wetlands in South Africa and coordinated through the Ornithological Research Station at the Barberspan Bird Sanctuary, then located in the Transvaal Province (now the North West Province), and implemented through the five provincial nature conservation agencies at the time. Data collection aimed at the abundance, breeding and moulting of ducks and geese (Anatidae) at major wetlands in South Africa, but also included other conspicuous waterbirds such as Red-knobbed Coot, Greater and Lesser Flamingo, and Great White and Pink-backed Pelican. All waterbird species were included in the censuses at most sites after a few years. Scientific names are contained in Appendix 1.2. The programme ended in the early 1990s. A large proportion of these data remains unpublished (C. Heÿl pers. comm.) but the programme did collect good quality data from specific wetlands over a 12–year period. Data from these surveys have been used here (Chapter 4, Appendices A–D).

In the 1970s, the Western Cape Wader Study Group (WCWSG) was established and there was a strong focus on carrying out 'wader' (shorebird) counts around the coastline of South Africa (Underhill 1979). Although there was a tendency to focus on Palearctic migrant species, resident species were also considered. Numerous surveys were undertaken and published under the auspices of the WCWSG (Summers et. al. 1976, 1977, Underhill et al. 1980), some even considering all waterbird species during the surveys (Underhill and Cooper 1984, Underhill 1987).

As the extent of waterbird surveys increased, so the number of waterbird studies grew after 1960. These studies took place at a site level or taxonomic level. I select a few key examples of studies: both Liversidge (1958) and Brooke (1960) studied waterfowl abundance on pans in the gold mining areas of the Free State; Geldenhuys (1976a, b) provided a provincial overview of abundance and breeding of waterfowl in the Free State; Skead and Dean (1977) carried out a thorough study of waterfowl at Barberspan Bird Sanctuary, North West Province; Martin and Baird (1987) provided an overview of waterbirds at the Swartkops Estuary, Port Elizabeth, Eastern Cape; both Martin and Randall (1987) and Velásquez et al. (1991) considered the usage and impact of waterbirds at commercial salt pans; Boshoff and Palmer (1991) and Boshoff et al. (1991a, b, c) analysed count and breeding survey data of waterbirds at coastal lakes in the Wilderness region of the southern Western Cape. In addition, bird atlas data were used to assess seasonality of migrant shorebird occurrence (Underhill et al. 1992) and waterfowl breeding seasonality in the Western, Eastern and Northern Cape provinces (Little et al. 1995). Counts at roosts of colonial waterbirds have also been undertaken (Tarboton 1977, Harebottle and Wheeler 2004) to provide better estimates of population sizes. Guillet and Crowe (1986) provided a preliminary overview of general patterns of waterbird distribution and diversity in southern Africa.

From a taxonomic perspective there have been numerous reviews and studies of individual species. From the 1950s to the 1970s there was a large emphasis on ducks and geese (e.g. Middelmiss 1958, Brand 1961, Rowan 1963, Siegfried 1965a, b, Winterbottom 1974), while a coastal seabird focus in the 1980s and 1990s produced species reviews for *inter alia* Cape Cormorant (Cooper et al. 1982), Kelp Gull (Crawford et al. 1982), Hartlaub's Gull (Williams et al. 1990), Swift Tern (Cooper et al. 1990 and Caspian Tern (Cooper et al. 1992). The Western Cape Wader Study Group was responsible for a series of papers on Palearctic migrant shorebirds: Curlew Sandpiper (Elliott et al. 1976), Sanderling (Summers et al. 1987), Ruddy Turnstone (Summers et al. 1989), Grey Plover (Serra et al. 2001) and Red Knot (Summers et al. 2010, 2011).

The studies mentioned above indicated the growing need for waterbird monitoring and documentation of results. Besides adding to scientific knowledge, the value of waterbirds as wetland indicators was becoming apparent (see Paillisson et al. 2002). However, most studies were largely confined to sites, habitats or species groups. Apart from the African Wildfowl Enquiry and South African Waterfowl Census programmes, which primarily focused on waterfowl, no coordinated programme existed to monitor all waterbirds at a national scale, and on an ongoing basis (Underhill et al. 1991).

The Coordinated Waterbird Counts – a new programme for a new era

In November 1991, the Coordinated Waterbird Counts (CWAC) programme was launched by the then Avian Demography Unit (now Animal Demography Unit) at the University of Cape Town, under the auspices of the Ramsar Working Group, a committee of the South African Department of Environmental Affairs and Tourism (DEAT) (Taylor et al. 1999). This was in response to South Africa's obligation to meet monitoring requirements under Wetland International's African Waterfowl Census (now African Waterbird Census) programme which had started in 1991. Participation in this programme also ensured that South Africa would meet its obligations as a signatory to the Ramsar Convention and Convention on Migratory Species (CMS) under the Bonn Convention to which South Africa acceded in 1991 (Cowan 1995).

The programme identified three primary aims (Taylor et al. 1999):

(1) to monitor populations of waterbirds by carrying out regular summer and winter counts at as many of South Africa's major wetlands as possible, on an ongoing basis;
(2) to identify and document the threats to waterbird populations and wetlands, and
(3) to coordinate the efforts of amateur volunteers and professional conservators in achieving (1) and (2).

In 1999, a six-year review of CWAC was published (Taylor et al. 1999) which provided initial useful site- and species-specific insights. The report concluded that *"…CWAC is producing important and meaningful results which are not available through any other wetland monitoring project…"*. It further emphasised that CWAC's importance is manifested in its ability to detect changes in bird populations and species diversity and not just to report on the numbers and variety of birds at site level. It was highlighted that the programme should continue at its present level, with the intention of increasing in scope.

Taylor et al. (1999) reported on 189 wetland sites; currently 650 sites are registered with the programme of which 450 (70%) are counted regularly (Animal Demography Unit unpubl. data, http://cwac.adu.org.za). By 2011, nearly 300 volunteers participated during each bi-annual census, and most undertook surveys at the same sites year after year.

Over the last two decades CWAC has made a significant contribution to our understanding of how waterbirds use wetlands in South Africa, and has radically improved on the amount, spread and integrity of data that is collected since the 1940s. Its value as a scientific and conservation tool is extremely valuable. It is for this reason that a large proportion of the data used in this thesis is derived from the CWAC database.

General methodology

Selection of the regional study sites

The wetlands that were selected for the site analyses in the winter rainfall region were based on the following criteria:

a. they had long-term (minimum 10 years) waterbird monitoring datasets which comprised a large bulk of monthly data;
b. species' representation was good at each site and numbers of waterbirds were large enough to make informed statements about their seasonality and abundance;
c. they represented a range of different wetland types within the winter rainfall region of the Western Cape;
d. they were spread across the entire winter-rainfall region of the Western Cape;
e. they represented various levels of protection, which would help assess and compare protected sites with unprotected sites;

A total of 30 wetlands were selected (Appendix 1.5). Detailed analyses were carried out at five representative wetlands: Paarl Waste Water Treatment Works, Bot River Estuary, Droëvlei Dam, Rocher Pan and De Hoop Vlei. Only the analysis for the Bot River estuary is included as part of the thesis as Chapter 4. The assessments for the remaining sites follow closely the pattern established by the analyses of the surveys conducted at the Bot River estuary, and are relegated to the status of Appendices to the thesis (Appendices A–D). Although the analyses are repetitive, each site had its own specific issues, and therefore it was deemed appropriate that the reports for each site should be included as Appendices to the thesis. The results of the analyses at these four sites were used in Chapters 2 and 5. The 30 wetlands were used in a regional comparison in Chapter 5.

Terminology

In the context of this thesis, it is important to define the terms 'wetlands' and 'waterbirds' from the outset. Terminology varies geographically and colloquial names are frequently encountered. By defining these terms here, I hope to avoid ambiguity and that this will assist in understanding some of the terminology used in this thesis.

Wetlands

The term wetland is commonly defined as an area of water-logged soils dominated by emergent vegetation (Maltby 1991); however, Davies and Day (1998) stated that technically 'wetlands are considered to include any ecosystems whose soils show evidence of at least periodic waterlogging.' Maltby (1991) further added that wetlands typically occupy zones between permanently wet and generally dry environments. Based on these definitions, areas of marsh and swamp are generally thought of as being true wetlands. However many different types of landscapes have open water in some way, whether it be in small pools, large lakes or rivers. Thus wetlands encompass many different kinds of waterbodies (Davies and Day 1998). Consequently, classification of wetlands has been relatively controversial due the enormous diversity of wetland types and their often highly dynamic characters (e.g. are temporary flooded areas included as wetlands when they are perhaps dry for the greater part of the year?). Therefore, for the purpose of this thesis, I use the Ramsar Convention (Convention on Wetlands of International Importance) definition (Ramsar 2010):

The convention defines wetlands as *"areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed 6 m".*

This definition (a) essentially covers much of the characteristics of wetlands and (b) is the universally accepted definition in terms of classifying wetlands of international importance for waterbirds, the latter being the focal reason for original designation of Ramsar sites, and (c) has been adopted by the South African authorities, through its membership of the Ramsar Convention, for its wetlands programmes (Cowan 1995).

Currently a total of 34 different wetland types constitute the Ramsar classification for wetlands, comprising 12 marine/coastal wetland types and 22 inland wetland types (Appendix 1.4, Ramsar 2010). Maltby (1991) highlighted that although this definition and classification is comprehensive and covers the complexity of wetland types, it should be borne in mind that wetlands exhibit enormous variation, some in the same wetland area, or at greater spatial scales where many different wetland types occur in close proximity and form distinct landscapes. Local scale differences could be manifested in subtle difference in flooding regimes. Nevertheless, wetlands will exhibit variation based on the following factors – genesis, geographical location, water regime and chemistry, dominant plants and soil or sediment characteristics. Maltby (1991) and Davies and Day (1998) concur that the dynamics of water supply and loss (i.e. hydrology) is probably the most critical factor in determining the development, maintenance and functioning of wetlands. These aspects impact on waterbirds and other wetland flora and fauna and so play vital ecological roles in the wetland ecosystem.

In South Africa, the vernacular term 'vlei' is commonly used but can have different meanings in different regions. In the northern parts it usually describes a reed-bed associated with a river course (similar to a marsh), while in the southern parts it is generally used to refer to any kind of wetland (Davies and Day 1998), but more frequently applied to large lake-like waterbodies with reed-beds. The term is often used to describe the name of the wetland e.g. Nylsvlei, De Hoop Vlei (Appendix D). The word is of Dutch/Afrikaans origin meaning 'pond', 'marsh', and is pronounced as "flay" (http://wikipedia.com).

Another South African colloquial wetland term is 'pan'. This term generally refers to any large, flat, sediment-filled depression that holds water after rainfall and which are endorheic in nature, having no outlet (Allan et al. 1995, Davies and Day 1998). If these pans are situated alongside river-courses these are then referred to as floodplain pans, and may hold water permanently. Pans that are fed by a river but have no outlet are usually considered lakes (Davies and Day 1998).

Waterbirds

For this thesis I use the definition based on the Ramsar Convention definition, and which is also used by Wetlands International (2006). The convention uses the term 'waterfowl' in the convention text but they have defined 'waterbird' as being synonymous with 'waterfowl' for the purposes of the application of the convention. The Ramsar definition states that waterbirds are defined as *"species of birds which are ecologically dependent on wetlands"*

Wetlands International (2006) definitions waterbirds to include all species of the families Gaviidae, Podicepedidae, Pelecanidae, Phalacrocoracidae, Anhingidae, Ardeidae, Balaenicipitidae, Scopidae, Ciconiidae, Threskiornithidae, Phoenicopteridae, Anhimidae, Anatidae, Pedionomidae, Gruidae, Aramidae, Rallidae, Heliornithidae, Eurypygidae, Jacanidae, Rostratulidae, Dromadidae, Haematopodidae, Ibidorhynchidae, Recurvirostridae, Burhinidae, Glareolidae, Charadriidae, Scolopacidae, Thinocoridae, Laridae, Sternidae, and Rynchopidae. Using this approach, only a minority of wetland bird populations are excluded and most of these are pelagic seabird species that venture occasionally into in-shore waters (Wetlands International 2006).

For the regional and site analyses (Chapters 3, 4, 5 and Appendices A–D) some of these waterbird families (Gaviidae, Balaenicipitidae, Anhimidae, Pedionomidae, Aramidae, Eurypygidae, Ibidorhynchidae, Thinocoridae) are not represented in South Africa, and are therefore excluded. The remaining families are well represented in South Africa and species within these families (Hockey et al. 1989, 2005) are discussed in this thesis.

All the waterbird species considered are listed with their common names and scientific names in Appendices 1.2 and 1.3; these are to be used as a reference for Chapters 2 and 3 respectively. Due to the nature of the regional analyses (Chapter 5), additional fields were included, namely: occurrence status, species group, feeding guild, Red Data status (if applicable) and preferred habitat for each species (Appendix 1.3). For scientific and vernacular names I have followed Hockey et al. (2005) and Wetlands International (2006) throughout this thesis. For the sake of brevity, I do not follow the normal convention of giving scientific names for species at first mention in each chapter; the scientific names are available in Appendices 1.2 and 1.3.

For occurrence status (in Chapter 5) birds were grouped into southern African residents and Palearctic migrants. Southern African residents are defined as species that breed in southern Africa and undertake local and/or long-distance movements within the region; the Greater Flamingo is the only species that can be regarded as truly migratory in this group moving regularly between their breeding grounds in Botswana and Namibia and other regions in southern Africa (Williams and Velásquez 1997). Palearctic migrants are those species that breed in the Palearctic region during the boreal summer (June–August) and then undertake long-distance migrations to spend the non-breeding season during the austral summer (September–April) in the southern hemisphere. In the thesis I refer to southern African residents as 'residents' or 'resident species' and Palearctic migrants as 'migrants' or 'migratory species'.

Species groups were categorised into waterfowl, cormorants and darter, pelicans, waders, flamingos, shorebirds, cranes, gulls, terns, rallids, and raptors. I use the term waterfowl to define 'open-water' species included in the Anatidae, Podicepedidae and two species in the Rallidae, Red-knobbed Coot and Common Moorhen. The African Darter is included with the cormorants due to the similar feeding habits of the two species groups. I use the terms 'waders' to refer to those species constituting the families Ardeidae, Scopidae, Ciconiidae, Threskiornithidae, Phoenicopteridae and Recurvirostridae, and 'shorebirds' for species in the Charadriidae and Scolopacidae families, thus following "American" conventions for these terms.

Species were grouped into four feeding guilds: herbivores, piscivores, invertebrate feeders and carnivores. Where a species' diet overlapped between two guilds the type of food making up the largest proportion was used to assign a species to a specific guild; dietary information was sourced from Hockey et al. (2005). This information is relevant to Chapters 4–5 particularly regarding data analysis, and mention or description of a species, its occurrence status, group or foraging guild should be cross-referenced with the table in Appendix 1.3.

Conservation assessment

A large focus of the thesis is the assessment of the conservation and global/regional importance of each of the selected sites based on the waterbird community present. This was done based on two sets of criteria: (1) identifying threatened species based on the threat status contained in Barnes (2000) and (2) assessing species which supported significant numbers of birds. In turn, this was done in two ways: firstly, using the standard Ramsar criteria, and secondly, using a new approach developed in this thesis. For the former, the Ramsar criteria and BirdLife International's Important Bird Area (IBA) sub-regional thresholds were used (Wetlands International 2006, Barnes 1998). The Ramsar criteria state that "a wetland should be considered important if it regularly supports 20 000 or more waterbirds and/or regularly supports 1% of the individuals in a population of one species, or sub-species of waterbird". The Ramsar 1% thresholds are also used by BirdLife International to designate Global IBAs, but in southern Africa a Sub-regional IBA category was introduced due to the mainly episodic nature of wetlands where the 1% level would rarely be applied. Here a 0.5% threshold was set to identify important wetlands in this category. The new approach to wetland conservation assessment is described and evaluated in Chapters 2 and 3.

Species were also assessed at provincial (Western Cape) and, where appropriate, metropole (Cape Town) levels using estimated values for their respective populations at these levels. The Cape Town metropole region is shown in Figure 1.5.

The 1% and 0.5% threshold levels and provincial and metropole population estimates are given in Appendix 1.4. Where results are given in each of the site analyses (Chapter 3 and Appendices A–D) concerning application of the 1% and 0.5% criteria, and provincial or metropole significance, reference should be made to this appendix for the actual threshold levels or population estimates.

Data and analysis considerations of the thesis

The seasonality, abundance and trend analyses for each of the five wetland sites in the Western Cape were similar (Chapter 4, Appendices A–D). The analysis at the Paarl Waste Water Treatment Works (Appendix A) was the first to be published (Harebottle et al. 2008). For this reason, the standard data analysis methods (abundance, seasonality and inter-annual variation) are described in more detail in Appendix A than in the other site analyses (Chapter 4, Appendices B–D).

I refer to southern hemisphere seasons: summer is defined as the six months from October to March and winter as the six months from April to September. Seasonality analyses were however carried out separately for residents and Palearctic migrants. Analyses for residents were based on the season definition above, while Palearctic migrants were analysed using summer as September–April and winter May–August. This was done because most Palearctic migrants start to arrive in September with last birds departing in April, and because this division was used by Kaletja-Summers et al. (2001a, b) and allows for comparisons between sites.

Constraints imposed by data

Waterbird censuses, by their nature, lend themselves to caveats and/or certain constraints. One limitation relates to observer skill where different observers have different levels of bird identification and counting skills (Spearpoint et al. 1988). The count data presented here (Chapter 4, Appendices A–D) were undertaken either by professional ornithologists, trained volunteers (usually bird club members) and/or conservation staff. Often turnover of observers at a site occurred, but when this happened the count methodology at the site remained consistent (e.g. routes, time of day) as much as possible to minimise the amount of variability in the counts and reduce the overall error in the dataset (Boshoff and Palmer 1993). Because all counters were trained observers, levels of species identification and counting were reasonably high and the accuracy of the surveys at species level was regarded as good.

Different waterbird species are variably conspicuous and this leads to different levels of count accuracy (Spearpoint et al. 1988). Counts of species that remain in the open were the most accurate as they were conspicuous and easy to count. However, numbers of cryptic species or those that may move between open water and aquatic vegetation (usually species within the Rallidae) were considered underestimates and abundance values were regarded as the 'minimum' number of birds present at the site.

Often a small proportion of birds in surveys cannot be identified to species; in all the surveys reported in this thesis, these birds were identified to groups: ducks, shorebirds, gulls or terns. This is seldom due to lack of skill on the part of the observers but is usually attributable to poor light conditions, and/or to flocks which are silhouettes too distant to be identified to species level with confidence, or to flocks which are mixed. These data have been consistently handled according to the following strategy. They have been included in the overall total for a survey. When calculating proportions for a given species, the overall total, including unidentified birds, has been included in the denominator, so that the correct proportion might be slightly larger than stated. This is a conservative approach. When calculating the percentage of birds which belong to a group (e.g. shorebirds), the unidentified birds of that group have been included in both the numerator and the denominator.

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Table 1.1 Key papers dealing with surveys of waterbirds at the larger wetlands in the Western Cape, South Africa, in chronological order of publication.

Locality	Comments	Reference(s)
Zeekoeivlei	Dealt only with Palearctic waders and the Barn Swallow *Hirundo rustica*.	Broekhuysen and Meiklejohn 1941
Langebaan Lagoon	Report on the status and abundance of waterbirds at the lagoon.	Liversidge et al. 1958
Wetlands of the Cape Peninsula	Report on monthly counts by members of the Cape Bird Club at vleis on the Cape Flats, many of which have disappeared under housing.	Winterbottom 1960
Strandfontein Sewage Works and Rietvlei, Milnerton	First detailed summary of waterbirds at these sites.	Blaker and Winterbottom 1968
Bot River Estuary	Summary of two years of waterbird surveys in lieu of artificial breaching	Branch et al. 1985; Heÿl and Currie 1985
Langebaan Lagoon	Update of population trends of mainly Palearctic shorebirds; some resident waterbird species also included.	Underhill 1987
Berg River Estuary	Study to determine abundance and habitat use by waterbirds in lower portions of the estuary.	Velásquez *et al.* 1991
Wilderness Lakes, Sedgefield	Ordination studies that looked at association of waterbirds on different waterbodies.	Boshoff *et al.* 1991a, b, c
Rietvlei, Milnerton	First study looking at long-term trends of waterbird populations at the site.	Kaletja-Summers et al. 2001a
Strandfontein Sewage Works	First study looking at long-term trends of waterbird populations at the site.	Kaletja-Summers et al. 2001b
Strandfontein Sewage Works	Dealt with overview of breeding outputs.	Ashkenazi 2001
Theewaterskloof Dam	First study looking at long-term trends of waterbird populations at the site.	Swanepoel et al. 2006.

Table 1.2 The 12 climatic zones in South Africa based on the Klöppen Class climate classification system (Schulze et al. 2007). For more characteristics of each zone refer to Appendix 1.2.

Köppen Class	Climatic Characteristics	Percentage of South Africa
Aw	Tropical wet, dry winter season	1.53%
BSh	Semi-arid, hot and dry	15.55%
BSk	Semi-arid, cool and dry	17.95%
BWh	Arid, hot and dry	16.34%
BWk	Arid, cool and dry	9.97%
Cfa	Wet all seasons, summers long and hot	4.69%
Cfb	Wet all seasons, summers long and cool	8.10%
Csa	Summers long, dry and hot	0.24%
Csb	Summers long, dry and cool	0.89%
Cwa	Winters long, dry and hot	10.10%
Cwb	Winters long, dry and cool	14.61%
Cwc	Winters dry, summers short and cool	0.02%

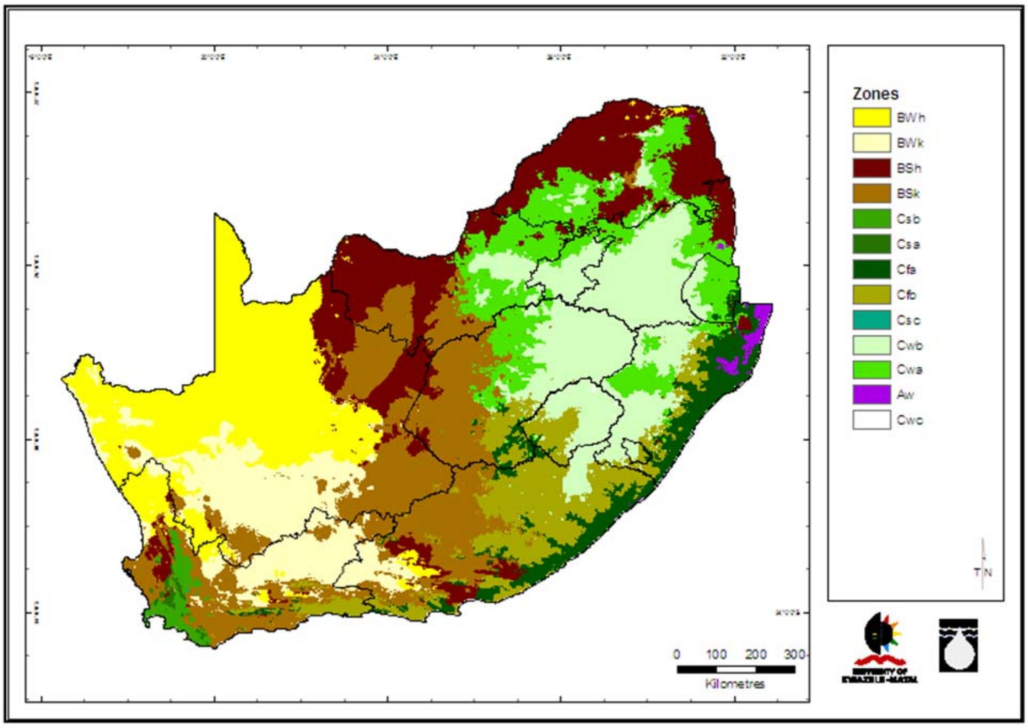


Figure 1.1 The 12 climatic zones in South Africa based on the Klöppen Class climate classification system. For explanation of the codes refer to Table 1.2 (Schulze et al. 2007).

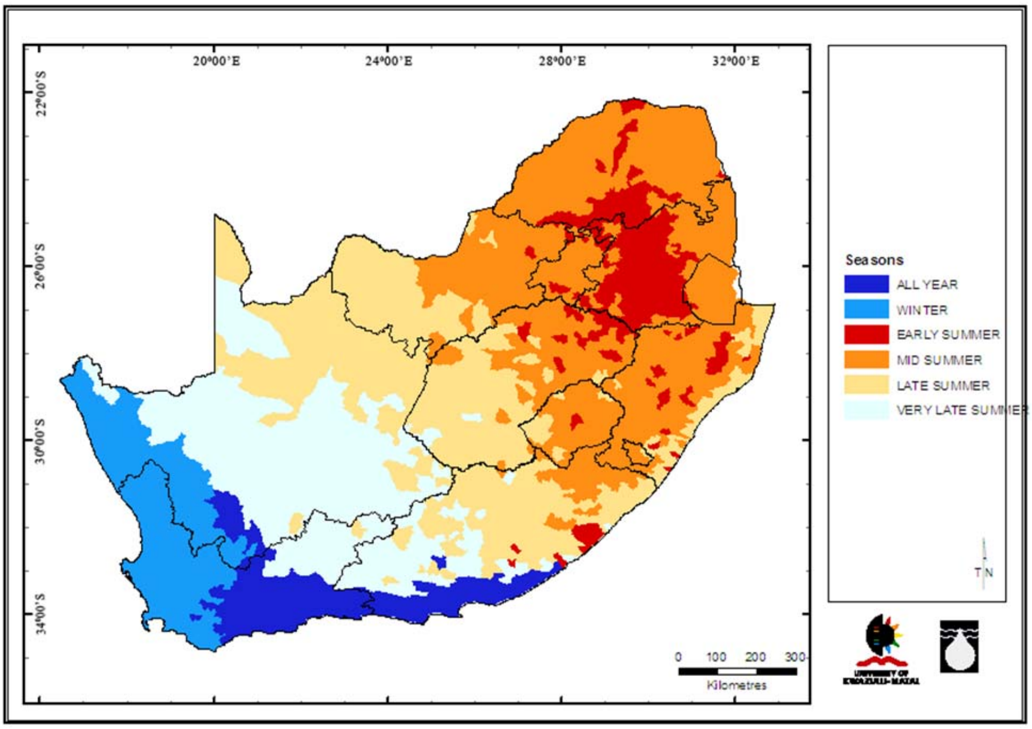


Figure 1.2 The six major rainfall zones in South Africa. The winter rainfall region is shaded in medium blue. From Schulze and Maharaj (2007).

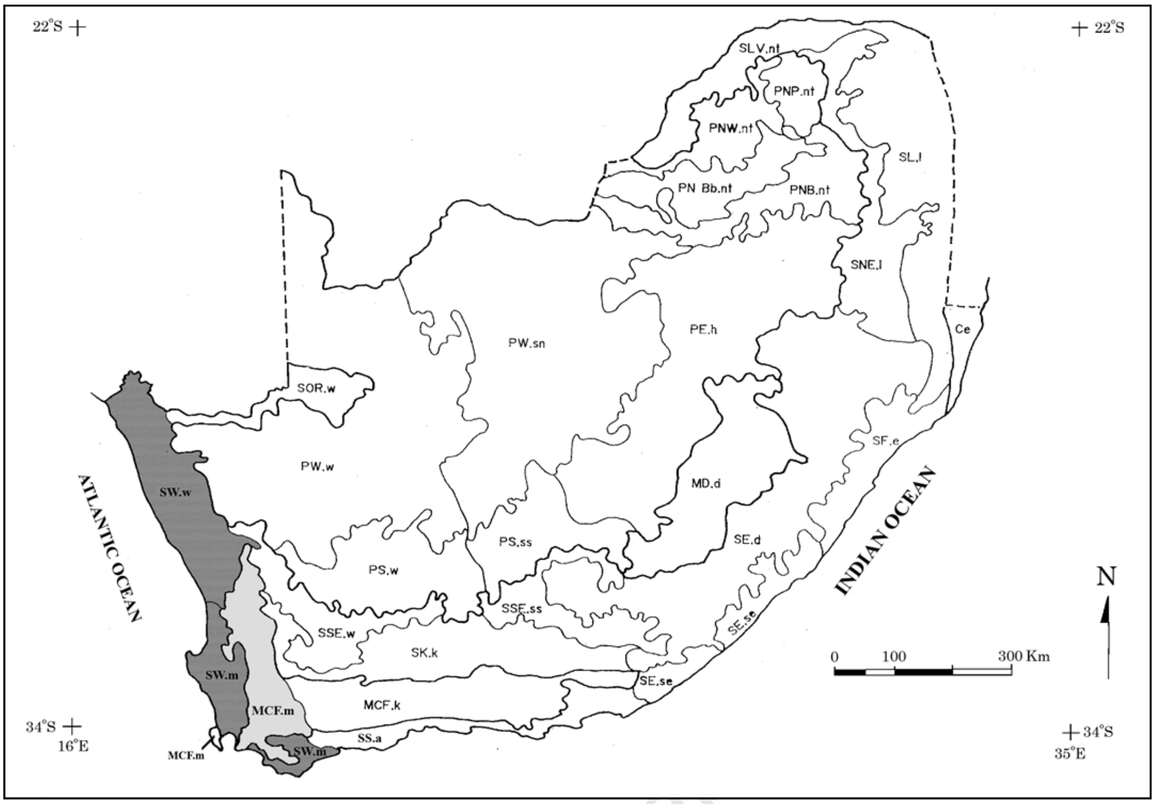


Figure 1.3 Wetland regions of South Africa (modified from Cowan 1995). The regions applicable to the winter rainfall region and referred to in this thesis are shaded in grey and labelled SW.w (Western coastal slope – desert), SW.m (Western coastal slope–Mediterranean) and MCF.m (Cape Fold Mountains – Mediterranean). For descriptions of other regions please refer to Cowan (1995, p.24).

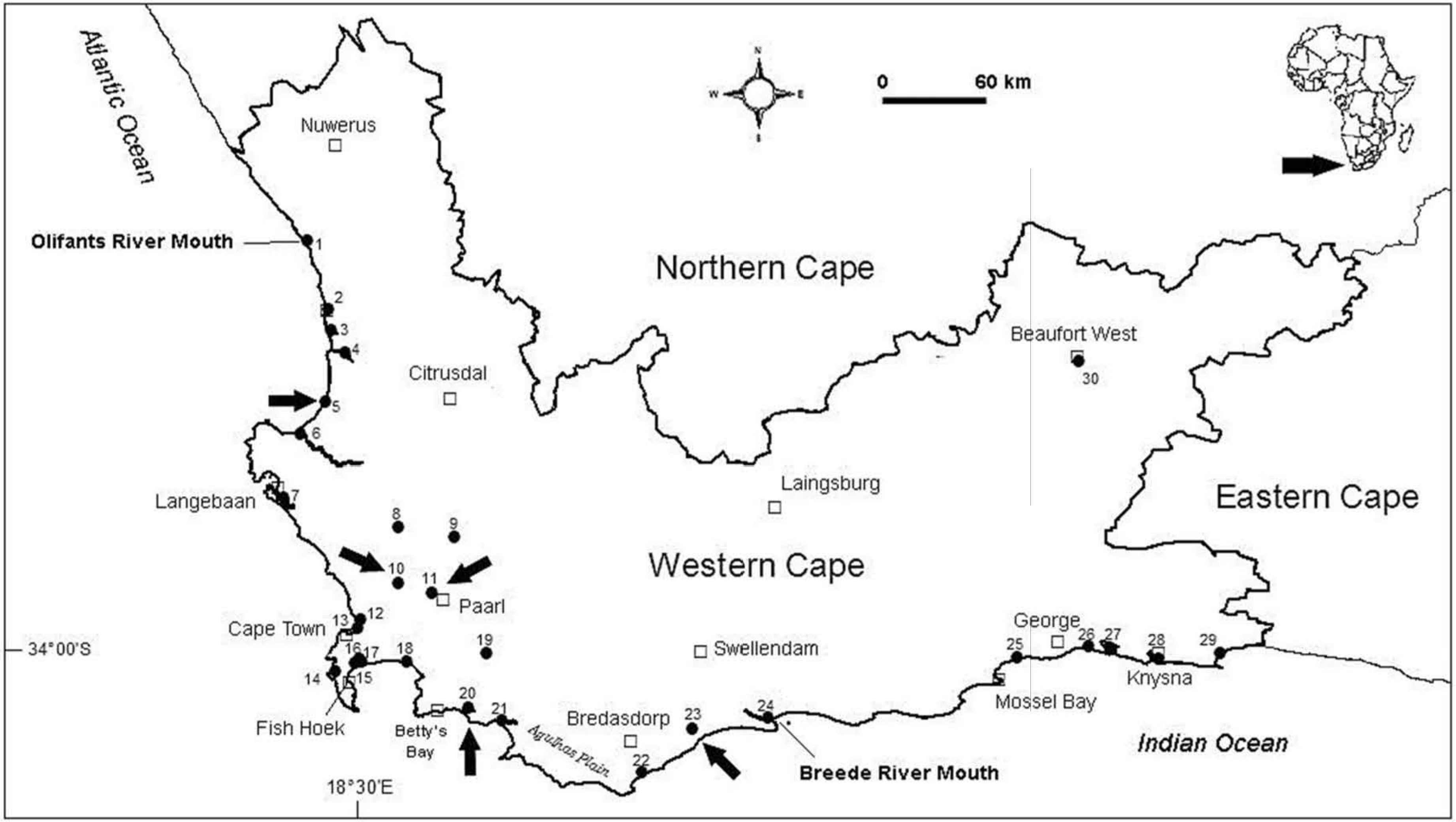


Figure 1.4 The location of 30 wetlands (numbered 1–30) in the Western Cape, South Africa that are dealt with in this thesis. Sites marked with arrows represent the five sites in Chapter 4 and Appendices A–D; 5 = Rocher Pan, 10 = Droëvlei Dam, 11 = Paarl Waste Water Treatment Works, 20 = Bot River Estuary and 23 = De Hoop Vlei For other site names refer to Appendix 1.5.

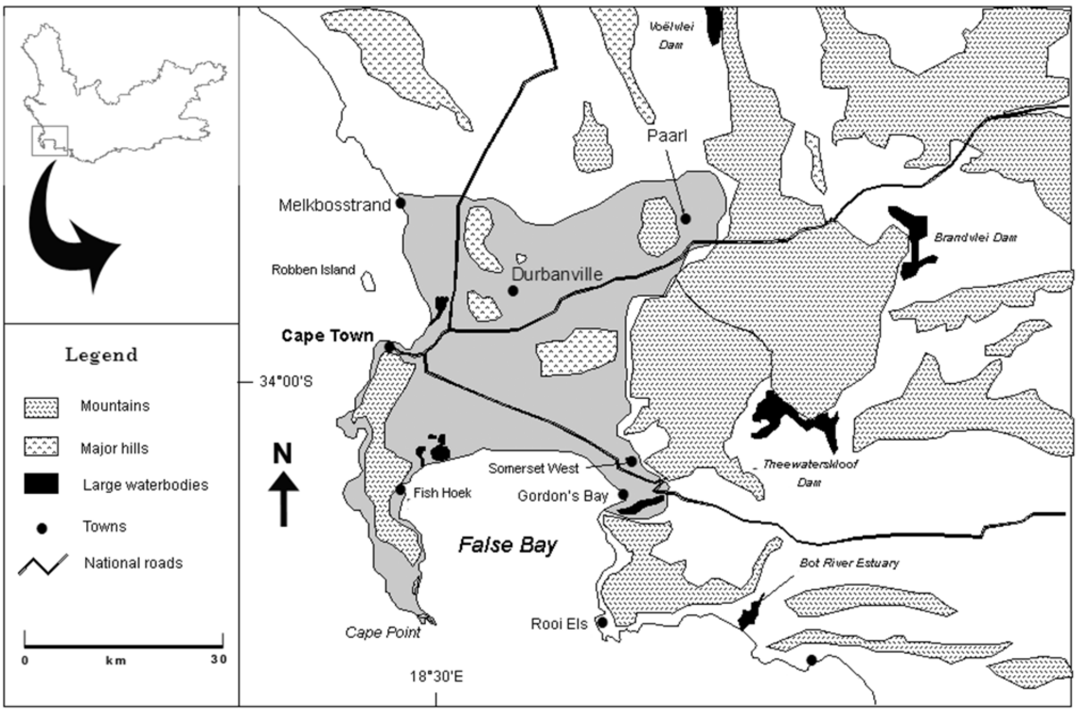


Figure 1.5 Cape Town metropole region (shaded grey). Major mountainous areas and large waterbodies are shown.

Appendix 1.1 Details of the Klöppen Class climate classification system (Schulze et al. 2007).

Letter symbol			Climate Characteristics	Criteria
1st	2nd	3rd		
A	-	-	Humid tropical	All months have an average temperature of >18oC
	f	-	Tropical wet (rain forest)	Wet all seasons; all months at least 60 mm rainfall
	w	-	Tropical wet & dry (savanna)	Winter dry season; rainfall in driest month < 60 mm and <100P/25 *(P = Mean Annual Precipitation, mm)*
	m	-	Tropical monsoon	Short dry season; rainfall in driest month < 60 mm, but ≥ 100-P/25
B	-	-	Dry	P<20(t+14) when ≥70% rain falls in warmer 6 months (dry winter) P<20t when ≥ 70% rain falls in cooler 6 months (dry summer) P<20(t+7) when neither half year has ≥ 70% rain
	S	-	Semi-arid (steppe)	10(t+14) < P<20(t+14) when ≥ 70% rain falls in warmer 6 months (dry winter) 10t <P< 20t when ≥ 70% rain falls in cooler 6 months (dry summer) 10(t+7) <P <20(t+7) when neither half year has ≥ 70% rain
	W	-	Arid (desert)	P <10(t+14) when ≥ 70% rain falls in warmer 6 months (dry winter) P< 10t when ≥ 70% rain falls in warmer 6 months (dry winter) P <10(t+7) when neither half year has ≥ 70% rain
	-	*h*	Hot and dry	Mean annual temperature is ≥18^{o}C
	-	*k*	Cool and dry	Mean annual temperature is < 18^{o}C
C	-	-	Moist with mild winters	Average temperature of coldest month < -3^{o}C; average temperature of warmest month > 10^{o}C
	w	-	Dry winters	Same as under *Cw*
	s	-	Dry summers	Same as under *Cs*
	f	-	Wet all seasons	Same as under *Cf*
	-	*a*	Summers long and hot	Same as under *Cfa*
	-	*b*	Summers long and cool	Same as under *Cfb*
	-	*c*	Summers short and cool	Same as under *Cfc*
D	-	-	Moist with cold winters	Average temperature of coldest month < -3^{o}C; average temperature of warmest month > 10^{o}C
	w	-	Dry winters	Same as under *Cw*
	s	-	Dry summers	Same as under *Cs*
	f	-	Wet at all seasons	Same as under *Cf*
	-	*a*	Summers long and hot	Same as under *Cfa*
	-	*b*	Summers long and cool	Same as under *Cfb*
	-	*c*	Summers short and cool	Same as under *Cfc*
	-	*d*	Summers short and cool; Winters severe	Average temperature of coldest month < -3^{o}C
E	-	-	Polar climate	Average temperature of warmest month <10^{o}C
	T	-	Tundra	Average temperature of warmest month >0^{o}C but < 10^{o}C
	F	-	Ice cap	Average temperature of warmest month < 0^{o}C

Appendix 1.2 List of species used in the analyses for Chapter 2. Common name, scientific name and 1% threshold levels for Western Europe and Western Africa are given 1% thresholds sourced from Wetlands International (2006).

English name	Scientific name	1% threshold level[1] (Ramsar/Global IBA)	
		Western Europe	Western Africa
African Darter	*Anhinga rufa*		250
African Openbill Stork	*Anastomus lamelligerus*	-	4000
African Purple Swamphen	*Porphyrio madagascariensis*	-	250
African Pygmy Goose	*Nettapus auritus*	-	100
African Sacred Ibis	*Threskiornis aethiopicus*	-	3300
African Skimmer	*Rynchops flavirostris*	-	100
African Spoonbill	*Platalea alba*	-	1000
Audouin's Gull	*Larus audouinii*	580	580
Barnacle Goose	*Branta leucopsis*	3600	-
Bar-tailed Godwit	*Limosa lapponica*	1200	5200
Bean Goose	*Anser fabalis*	800	-
Bewick's Swan	*Cygnus columbianus*	200	-
Black Heron	*Egretta ardesiaca*	-	1000
Black Stork	*Ciconia nigra*	-	15
Black Tern	*Chlidonias niger*	-	4000
Black-crowned Crane	*Balearica pavonina*	-	150
Black-crowned Night-heron	*Nycticorax nycticorax*	290	790
Black-headed Heron	*Ardea melanocephala*	-	3000
Black-legged Kittiwake	*Rissa tridactyla*	20000	-
Black-necked Grebe	*Podiceps nigricollis*	2800	2800
Black-tailed Godwit	*Limosa limosa*	1700	1700
Black-throated Diver	*Gavia arctica*	10000	-
Black-winged Stilt	*Himantopus himantopus*	770	770
Caspian Gull	*Larus cachinnans*	20000	-
Caspian Tern	*Sterna caspia*	65	65
Cattle Egret	*Bubulcus ibis*	2800	2800
Comb Duck	*Sarkidonis melanotus*	-	750
Common Black-headed Gull	*Larus ridibundus*	20000	15000
Common Coot	*Fulica atra*	17500	20000
Common Crane	*Grus grus*	750	-
Common Eider	*Somateria mollissima*	750	-
Common Goldeneye	*Bucephala clangula*	4000	-
Common Greenshank	*Tringa nebularia*	3100	3100
Common Gull	*Larus canus*	17000	-
Common Moorhen	*Gallinula chloropus*	20000	20000
Common Pochard	*Aythya ferina*	3500	10000
Common Pratincole	*Glareola pratincola*	190	190
Common Redshank	*Tringa totanus*	2500	2500
Common Ringed Plover	*Charadrius hiaticula*	730	1900
Common Sandpiper	*Actitis hypoleucos*	17000	17000
Common Scoter	*Melanitta nigra*	16000	-
Common Shelduck	*Tadorna tadorna*	3000	750
Common Snipe	*Gallinago gallinago*	20000	20000
Common Teal	*Anas crecca*	10600	10600
Common Tern	*Sterna hirundo*	1900	1900
Common Whimbrel	*Numenius phaeopus*	2300	6100
Curlew Sandpiper	*Calidris ferruginea*	7400	7400
Dark-Bellied Brent Goose	*Branta bernicla*	2000	-
Dunlin	*Calidris alpina*	1300	13300
Egyptian Goose	*Alopochen aegypticus*	-	180
Eurasian Bittern	*Botaurus stellaris*	65	-
Eurasian Curlew	*Numenius arquata*	4200	4200
Eurasian Golden Plover	*Pluvialis apricaria*	8000	8000
Eurasian Oystercatcher	*Haematopus ostralegus*	10200	10200
Eurasian Spoonbill	*Platalea leucorodia*	100	100
Eurasian Wigeon	*Anas penelope*	15000	3000
Eurasian Woodcock	*Scolopax rusticola*	20000	-

Appendix 1.2 contd

English name	Scientific name	1% threshold level[1] (Ramsar/Global IBA)	
		Western Europe	Western Africa
European Shag	*Phalacrocorax aristotelis*	2400	-
European White-fronted Goose	*Anser albifrons*	10000	-
Ferruginous Duck	*Aythya nyroca*	30	-
Fulvous Duck	*Dendrocygna bicolor*	-	1000
Gadwall	*Anas strepera*	600	1100
Garganey	*Anas querquedula*	20000	20000
Glossy Ibis	*Plegadis falcinellus*	530	15000
Goosander	*Mergus merganser*	2500	-
Great Black-backed Gull	*Larus marinus*	4700	-
Great Cormorant	*Phalacrocorax carbo*	1200	-
Great Crested Grebe	*Podiceps cristatus*	4800	-
Great Northern Diver	*Gavia immer*	50	-
Great Snipe	*Gallinago media*	10000	10000
Great White Egret	*Ardea alba*	470	3000
Great White Pelican	*Pelecanus onocrotalus*	-	600
Greater Flamingo	*Phoenicopterus ruber*	1000	400
Greater Scaup	*Aythya marila*	3100	-
Greater White-fronted Goose	*Anser albifrons*	10000	-
Green Sandpiper	*Tringa ochropus*	14500	14500
Green-backed Heron	*Butroides striatus*	-	10000
Grey Heron	*Ardea cinerea*	2700	10000
Grey Plover	*Pluvialis squatarola*	2500	2500
Grey-headed Gull	*Larus cirrocephalus*	-	300
Greylag Goose	*Anser anser*	4000	250
Gull-billed Tern	*Gelochelidon nilotica*	130	130
Herring Gull	*Larus argentatus*	11000	-
Kentish Plover	*Charadrius alexandrinus*	660	660
Kittlitz's Plover	*Charadrius pecuarius*	-	350
Lesser Black-backed Gull	*Larus fuscus*	5300	5300
Lesser Flamingo	*Phoenicopterus minor*		150
Little Egret	*Egretta garzetta*	1300	1300
Little Grebe	*Tachybaptus ruficollis*	3400	1000
Little Gull	*Larus minutus*	840	-
Little Ringed Plover	*Charadrius dubius*	2400	2400
Little Stint	*Calidris minuta*	2000	2000
Little Tern	*Sterna albifrons*	340	340
Long-tailed Duck	*Clangula hyemalis*	20000	-
Mallard	*Anas platyrhynchos*	20000	10000
Marbled Teal	*Marmaronetta angustirostris*	40	-
Marsh Sandpiper	*Tringa stagnatilis*		370
Mediterranean Gull	*Larus melanocephalus*	8400	-
Mute Swan	*Cygnus olor*	2500	-
Northern Lapwing	*Vanellus vanellus*	20000	20000
Northern Pintail	*Anas acuta*	600	10000
Northern Shoveler	*Anas clypeata*	400	4500
Pied Avocet	*Recurvirostra avosetta*	730	730
Pink-backed Pelican	*Pelecanus*	-	750
Pink-footed Goose	*Anser brachyrhynchus*	2770	-
Purple Heron	*Ardea purpurea*	120	120
Purple Sandpiper	*Calidris maritima*	750	-
Purple Swamphen	*Porphyrio porphyrio*	250	-
Red Knot	*Calidris canutus*	4500	3400
Red-breasted Merganser	*Mergus merganser*	1700	-
Red-crested Pochard	*Aythya ferina*	500	-
Red-knobbed Coot	*Fulica cristata*	-	80
Red-necked Grebe	*Podiceps grisegena*	1000	-
Red-throated Diver	*Gavia stellata*	10000	-
Reed Cormorant	*Phalacrocorax africanus*	-	1000
Royal Tern	*Sterna maxima*	-	1500

Appendix 1.2 contd

English name	Scientific name	1% threshold level[1] (Ramsar/Global IBA)	
		Western Europe	Western Africa
Ruddy Turnstone	*Arenaria interpres*	1000	830
Ruff	*Philomachus pugnax*	20000	20000
Sanderling	*Calidris alba*	1200	1200
Sandwich Tern	*Sterna bergii*	1700	1700
Senegal Thick-knee	*Burhinus senegalensis*	-	250
Slavonian Grebe	*Podiceps auritus*	35	-
Slender-billed Gull	*Larus genei*	1800	230
Smew	*Mergellus albellus*	400	-
Spotted Redshank	*Tringa erythropus*	1000	1000
Spur-winged Goose	*Plectropterus gambensis*	-	1000
Spur-winged Lapwing	*Vanellus spinosus*	-	4000
Squacco Heron	*Ardeola ralloides*	-	40
Stone Curlew	*Burhinus oedicnemus*	1400	-
Taiga Bean Goose	*Anser fabalis*	1000	-
Temminck's Stint	*Calidris temminckii*	600	600
Tufted Duck	*Aythya fuligula*	12000	7000
Tundra Bean Goose	*Anser fabalis*	6000	-
Velvet Scoter	*Melanitta fusca*	10000	-
Water Rail	*Rallus aquaticus*	10000	-
Western Reef Egret	*Egretta gularis*	-	1000
Western Yellow-legged Gull	*Larus michahellis*	7000	-
Whiskered Tern	*Chlidonias hybrida*	260	260
White Stork	*Ciconia ciconia*	930	930
White-breasted Cormorant	*Phalacrocorax lucidus*	-	350
White-faced Duck	*Dendrocygna viduata*	-	3800
White-fronted Plover	*Charadrius marginatus*	-	130
Whooper Swan	*Cygnus cygnus*	590	-
Wood Sandpiper	*Tringa glareola*	-	10400
Yellow-billed Egret	*Egretta intermedia*	-	1000
Yellow-billed Stork	*Mycteria ibis*	-	750

[1] Threshold levels sourced from Wetlands International (2006) and represent levels for global and biogeographical (southern Africa) populations. These are based on criterion set out in the Ramasr Convention.

Appendix 1.3 List of species used in the analyses for Chapters 3 and 5, and Appendices A–D. Common name, scientific name, occurrence status, group foraging guild, IUCN threat status, and habitat preference are given for each species. Species are listed in taxonomic order according to Hockey et al. (2005). All information sourced from Hockey et al. (2005) except for IUCN threat status which is taken from Barnes (1998). Habitat preference sourced from Kaletja-Summers (2001 a, b) and Hockey et al. (2005). Species marked in italics are endemic to southern Africa.

Common name	Scientific name	Occurrence status[1]	Species group[2]	Feeding guild[3]	Threat status[4]	Habitat[5]	Mass (g)[6]
White-faced Duck	*Dendrocygna viduata*	Res.	Waterfowl	I	–	OW	–
White-backed Duck	*Thalassornis leuconotus*	Res.	Waterfowl	H	–	OW	–
Maccoa Duck	*Oxyura maccoa*	Res.	Waterfowl	I	–	OW	659
Egyptian Goose	*Alopochen aegyptiaca*	Res.	Waterfowl	H	–	OW	1990
South African Shelduck	*Tadorna cana*	Res.	Waterfowl	I	–	OW	1240
Spur-winged Goose	*Plectropterus gambensis*	Res.	Waterfowl	H	–	OW	4480
Cape Teal	*Anas capensis*	Res.	Waterfowl	I	–	OW	402
Yellow-billed Duck	*Anas undulata*	Res.	Waterfowl	H	–	OW	412
Cape Shoveler	*Anas smithii*	Res.	Waterfowl	I	–	OW	643
Red-billed Teal	*Anas erythrorhyncha*	Res.	Waterfowl	H	–	OW	569
Southern Pochard	*Netta erythrophthalma*	Res.	Waterfowl	H	–	OW	818
Half-collared Kingfisher	*Alcedo semitorquata*	Res.	Kingfishers	P	NT	OW	–
Malachite Kingfisher	*Alcedo cristata*	Res.	Kingfishers	P	–	OW	17
Giant Kingfisher	*Megaceryle maximus*	Res.	Kingfishers	P	–	OW	364
Pied Kingfisher	*Ceryle rudis*	Res.	Kingfishers	P	–	OW	84
Marsh Owl	*Asio capensis*	Res.	Raptors	C	–	SEV	–
Blue Crane	*Anthropoides paradiseus*	Res.	Cranes	H	VU	SEV	–
African Rail	*Rallus caerulescens*	Res.	Rallids	I	–	SEV	–
Black Crake	*Amaurornis flavirostris*	Res.	Rallids	I	–	SEV	–
Baillon's Crake	*Porzana pusilla*	Res.	Rallids	I	–	SEV	–
African Purple Swamphen	*Porphyrio madagascariensis*	Res.	Rallids	H	–	SEV	596
Common Moorhen	*Gallinula chloropus*	Res.	Waterfowl	H	–	OW	247
Red-knobbed Coot	*Fulica cristata*	Res.	Waterfowl	H	–	OW	737
African Snipe	*Gallinago nigripennis*	Res.	Shorebirds	I	–	SEV	122
Bar-tailed Godwit	*Limosa lapponica*	Pal.	Shorebirds	I	–	BSM	264
Common Whimbrel	*Numenius phaeopus*	Pal.	Shorebirds	I	–	BSM	402
Eurasian Curlew	*Numenius arquata*	Pal.	Shorebirds	I	–	BSM	590
Marsh Sandpiper	*Tringa stagnatilis*	Pal.	Shorebirds	I	–	BSM	69
Common Greenshank	*Tringa nebularia*	Pal.	Shorebirds	I	–	BSM	175
Wood Sandpiper	*Tringa glareola*	Pal.	Shorebirds	I	–	SEV	60
Terek Sandpiper	*Xenus cinereus*	Pal.	Shorebirds	I	–	BSM	–
Common Sandpiper	*Actitis hypoleucos*	Pal.	Shorebirds	I	–	BSM	47
Ruddy Turnstone	*Arenaria interpres*	Pal.	Shorebirds	I	–	BSM	101
Red Knot	*Calidris canutus*	Pal.	Shorebirds	I	–	BSM	–
Sanderling	*Calidris alba*	Pal.	Shorebirds	I	–	BSM	55
Little Stint	*Calidris minuta*	Pal.	Shorebirds	I	–	BSM	23

Appendix 1.3 contd

Common name	Scientific name	Occurrence status[1]	Species group[2]	Feeding guild[3]	Threat status[4]	Habitat[5]	Mass (g)[6]
Curlew Sandpiper	*Calidris ferruginea*	Pal.	Shorebirds	I	–	BSM	57
Ruff	*Philomachus pugnax*	Pal.	Shorebirds	I	–	BSM	132
Greater Painted-snipe	*Rostratula benghalensis*	Res.	Shorebirds	I	NT	BSM	–
Water Thick-knee	*Burhinus vermiculatus*	Res.	Shorebirds	I	–	BSM	304
African Black Oystercatcher	*Haematopus moquini*	Res.	Shorebirds	I	NT	BSM	699
Black-winged Stilt	*Himantopus himantopus*	Res.	Waders	I	–	BSM	165
Pied Avocet	*Recurvirostra avosetta*	Res.	Shorebirds	I	–	BSM	323
Grey Plover	*Pluvialis squatarola*	Pal.	Shorebirds	I	–	BSM	218
Common Ringed Plover	*Charadrius hiaticula*	Pal.	Shorebird	I	–	BSM	50
Kittlitz's Plover	*Charadrius pecuarius*	Res.	Shorebirds	I	–	BSM	36
Three-banded Plover	*Charadrius tricollaris*	Res.	Shorebirds	I	–	BSM	33
Chestnut-banded Plover	*Charadrius pallidus*	Res.	Shorebirds	I	NT	BSM	–
White-fronted Plover	*Charadrius marginatus*	Res.	Shorebirds	I	–	BSM	46
Blacksmith Lapwing	*Vanellus armatus*	Res.	Waders	I	–	BSM	163
Kelp Gull	*Larus dominicanus*	Res.	Gulls	P	–	OW	1008
Grey-headed Gull	*Larus cirrocephalus*	Res.	Gulls	I	–	OW	280
Hartlaub's Gull	*Larus hartlaubii*	Res.	Gulls	I	–	OW	279
Caspian Tern	*Sterna caspia*	Res.	Terns	P	NT	OW	690
Swift Tern	*Sterna bergii*	Res.	Terns	P	–	OW	394
Sandwich Tern	*Sterna sandvicensis*	Pal.	Terns	P	–	OW	220
Common Tern	*Sterna hirundo*	Pal.	Terns	P	–	OW	131
Arctic Tern	*Sterna paradisaea*	Pal.	Terns	P	–	OW	–
Antarctic Tern	*Sterna vittata*	Pal.	Terns	P	–	OW	–
Little Tern	*Sterna albifrons*	Pal.	Terns	P	–	OW	–
Damara Tern	*Sterna balaenarum*	Res.	Terns	P	EN	OW	–
Whiskered Tern	*Chlidonias hybrida*	Res.	Terns	I	–	OW	100
White-winged Tern	*Chlidonias leucopterus*	Pal.	Terns	I	–	OW	54
Black Tern	*Chlidonias niger*	Pal.	Terns	I	–	OW	–
Osprey	*Pandion haliaetus*	Pal.	Raptors	P	–	OW	1485
African Fish-Eagle	*Haliaeetus vocifer*	Res.	Raptors	P	–	OW	–
African Marsh-Harrier	*Circus ranivorus*	Res.	Raptors	C	VU	TEV	501
Black Harrier	*Circus maurus*	Res.	Raptors	C	NT	TEV	–
Little Grebe	*Tachybaptus ruficollis*	Res.	Waterfowl	I	–	OW	146
Great Crested Grebe	*Podiceps cristatus*	Res.	Waterfowl	P	–	OW	621
Black-necked Grebe	*Podiceps nigricollis*	Res.	Waterfowl	I	–	OW	298
African Darter	*Anhinga rufa*	Res.	Cormorants[2]	P	–	OW	1508
Reed Cormorant	*Phalacrocorax africanus*	Res.	Cormorants	P	–	OW	555
Crowned Cormorant	*Phalacrocorax coronatus*	Res.	Cormorants	P	NT	OW	–
White-breasted Cormorant	*Phalacrocorax lucidus*	Res.	Cormorants	P	–	OW	2980
Bank Cormorant	*Phalacrocorax neglectus*	Res.	Cormorants	P	VU	OW	–

Appendix 1.3 contd

Common name	Scientific name	Occurrence status[1]	Species group[2]	Feeding guild[3]	Threat status[4]	Habitat[5]	Mass (g)[6]
Cape Cormorant	*Phalacrocorax capensis*	Res.	Cormorants	P	NT	OW	1220
Little Egret	*Egretta garzetta*	Res.	Waders	I	–	SEV	521
Yellow-billed Egret	*Egretta intermedia*	Res.	Waders	P	–	SEV	894
Great Egret	*Egretta alba*	Res.	Waders	P	–	SEV	1110
Grey Heron	*Ardea cinerea*	Res.	Waders	P	–	SEV	1435
Black-headed Heron	*Ardea melanocephala*	Res.	Waders	I	–	TERR	1440
Goliath Heron	*Ardea goliath*	Res.	Waders	P	–	TEV	–
Purple Heron	*Ardea purpurea*	Res.	Waders	P	–	TEV	873
Cattle Egret	*Bubulcus ibis*	Res.	Waders	I	–	TERR	374
Squacco Heron	*Ardeola ralloides*	Res.	Waders	F	–	SEV	–
Black-crowned Night-Heron	*Nycticorax nycticorax*	Res.	Waders	P	–	SEV	636
Little Bittern	*Ixobrychus minutus*	Res.	Waders	I	–	SEV	–
Hamerkop	*Scopus umbretta*	Res.	Waders	I	–	BSM	–
Greater Flamingo	*Phoenicopterus ruber*	Res.	Flamingos	I	NT	OW	3470
Lesser Flamingo	*Phoenicopterus minor*	Res.	Flamingos	H	NT	OW	1725
Glossy Ibis	*Plegadis falcinellus*	Res.	Waders	I	–	SEV	634
Hadeda Ibis	*Bostrychia hagedash*	Res.	Waders	I	–	SEV	1280
African Sacred Ibis	*Threskiornis aethiopicus*	Res.	Waders	I	–	SEV	1500
African Spoonbill	*Platalea alba*	Res.	Waders	I	–	OW	1560
Great White Pelican	*Pelecanus onocrotalus*	Res.	Pelicans	P	NT	OW	9520
Black Stork	*Ciconia nigra*	Res.	Waders	I	NT	OW	–

[1] Res. = Southern African resident, Pal. = Palearctic migrant
[2] African Darter has been included with the cormorant group due to similar feeding habits.
[3] H= Herbivore, I = Invertebrate feeder, P = Piscivore, C = Carnivore
[4] EN = Endangered, VU = Vulnerable, NT = Near-threatened
[5] OW = Open water, SEV Short emergent vegetation = BSM = Bare shoreline/mudflats, TEV = Tall emergent vegetation, TERR = Terrestrial
[6] Only those species whose mass was used in the calculation of Field Metabolic Rate (Chapter 5) are given.

Appendix 1.4 Global and sub-regional IBA population threshold levels and estimated Western Cape and Cape Town metropole populations of waterbirds used in Chapter 3 and Appendices A–D.

Species	Threshold level		Estimated population size	
	Ramsar (1%)[1]	Sub-regional IBA (0.5%)[2]	Western Cape[3]	Cape Town metropole
African Black Oystercatcher	55	28	693	124
African Darter	1000	500	2895	993
African Fish Eagle	–	–	202	66
African Marsh Harrier	–	–	150	45
African Purple Swamphen	1000	500	251	145
African Sacred Ibis	3300	1650	9744	4908
African Snipe	250	125	364	225
African Spoonbill	1000	500	2422	376
Arctic Tern	20000[a]	-	222	25
Bank Cormorant	100	50	50*	?
Bar-tailed Godwit	5200	2600	771	1
Black Crake	10000	5000	103	38
Black Harrier	–	–	6	1
Black Stork	30	15	19	–
Black-crowned Night-heron	20000	20000	555	272
Black-headed Heron	3000	1500	656	267
Black-necked Grebe	150	75	4879	1640
Blacksmith Lapwing	10000	5000	5844	2517
Black-winged Stilt	230	115	7089	2195
Cape Cormorant	2200	1100	57942	51439
Cape Shoveler	350	175	12345	4223
Cape Teal	1750	875	7906	2862
Caspian Tern	15	8	689	129
Cattle Egret	10000	5000	7420	3774
Chestnut-banded Plover	110	55	798	1
Common Greenshank	3100	1550	4419	295
Common Moorhen	1000	500	2213*	1209*
Common Ringed Plover	1900	950	3742	477
Common Sandpiper	15000[a]	15000	2201	139
Common Tern	6400	3200	31240	7469
Common Whimbrel	10000	5000	2445	18
Crowned Cormorant	85	43	247	21
Curlew Sandpiper	3300	1650	58135	3611
Damara Tern	140	70	11*	?
Egyptian Goose	3500	1750	42041	9055
Fulvous Duck			99	67
Eurasian Curlew	1000	500	1535	4
Giant Kingfisher	–	–	104	39
Glossy Ibis	15000	7500	1909	924
Goliath Heron	250	125	45	1
Great Crested Grebe	100	50	1617	277
Great Egret	3000	1500	98	14
Great White Pelican	200	100	4637	1267
Greater Flamingo	760	380	26761	7331
Greater Painted-snipe	1000	500	33*	21*
Grey Heron	10000	5000	1534	363
Grey Plover	2500	1250	7512	143
Grey-headed Gull	3000	1500	1294	353
Hadeda Ibis	1000	500	897*	205*
Half-collared Kingfisher	–	–	16	5

Appendix 1.4 contd

Species	Threshold level		Estimated population size	
	Ramsar (1%)[1]	Sub-regional IBA (0.5%)[2]	Western Cape[3]	Cape Town metropole
Hamerkop	10000	5000	85	10
Hartlaub's Gull	300	150	18398	10806
Kelp Gull	700	350	21057	7714
Kittlitz's Plover	1000	500	6415	956
Lesser Flamingo	600	300	9024	2424
Little Bittern	1000	500	42	27
Little Egret	3500	1750	1715	208
Little Grebe	1000	500	8216	3274
Little Stint	10000	5000	19129	4483
Little Tern	365	183	196	71
Maccoa Duck	100	50	1625	757
Malachite Kingfisher	–	–	165	75
Marsh Owl	–	–	3*	3*
Marsh Sandpiper	750	380	1685	266
Osprey	–	–	54	2
Pied Avocet	190	95	8941	3844
Pied Kingfisher	–	–	607	96
Purple Heron	880	440	284	102
Red Knot	3400	1700	2597	3
Red-billed Teal	7500	3750	6130	2244
Red-knobbed Coot	10000	5000	81471	6874
Reed Cormorant	10000	5000	8004	1827
Ruddy Turnstone	1000	500	4691	32
Ruff	20000[a]	10000[a]	8197	1809
Sanderling	1400	700	4253	78
Sandwich Tern	1700	850	7573	3445
South African Shelduck	500	250	10496	280
Southern Pochard	500	250	4291	2592
Spur-winged Goose	750	375	5780	1231
Squacco Heron	–	–	16	7
Swift Tern	200	100	7869	2116
Terek Sandpiper	10000	5000	277	1
Three-banded Plover	1000	500	2028	400
Water Thick-knee	1000	500	315	108
Whiskered Tern	100	50	1026	207
White-backed Duck	180	90	1041	354
White-breasted Cormorant	120	60	6553	1563
White-faced Duck	10000	5000	306	192
White-fronted Plover	180	90	1675	45
White-winged Tern	20000	10000	19291	15793
Wood Sandpiper	20000	10000	516	132
Yellow-billed Duck	1000	500	18877	4513
Yellow-billed Egret	1000	500	334	147

[1] Threshold levels sourced from Wetlands International (2006) and represent levels for global and biogeographical (southern Africa) populations. These are based on criterion set out in the Ramasr Convention. Also represents the 1% Global IBA thresholds.

[2] Threshold sourced from Barnes (1998) to identify Sub-regional IBAs in southern Africa.

[3] Figure refers to sum of maximum count across all major wetlands in the Western Cape or Cape Town metropole and represents the estimated minimum population in the these regions. Data sourced from Coordinated Waterbird Counts (Animal Demography Unit, unpubl. data, 2006).

* Due to the cryptic nature of the species or association with terrestrial habitats these figures should be treated as absolute minimum estimates and therefore interpreted with caution.

Appendix 1.5 Summary of 30 wetland sites in the Western Cape, South Africa. Sites sorted in ascending order based on site no. (Figure 1.4). Sites in bold indicate the five representative sites used in Chapter 4 and Appendices A–D.

Site no.	Site name	Site code[1]	Coordinates		Wetland type	Hydrology[2]	Estuarine bio-region[2]	Conservation status
1	Olifants River Mouth	ol	31°41S	18°12E	Estuary	Permanently open	Cold temperate	Unprotected
2	Jakkalsvlei	jk	32°05S	18°19E	Coastal lake	Temporarily inundated	—	Unprotected
3	Wadrif Saltpan	ws	32°12S	18°20E	Coastal lake	Temporarily inundated	—	Unprotected
4	Verlorenvlei	vv	32°19S	18°24E	Estuary	Permanently inundated	—	Unprotected
5	**Rocher Pan**	**RP**	32°19S	18°23E	Coastal lake	Temporarily inundated	—	Protected
6	Berg River Estuary	bg	32°47S	18°09E	Estuary	Permanently open	Cold temperate	Unprotected
7	Langebaan Lagoon	lb	33°08S	18°03E	Estuarine bay	Permanently open	Cold temperate	Protected
8	Radyn Dam	rd	33°18S	18°43E	Farm dam	Temporarily inundated	—	Unprotected
9	Voelvlei Dam	wa	33°22S	19°02E	State dam	Permanently inundated	—	Unprotected
10	**Droëvlei Dam**	**DV**	33°59S	18°10E	Farm dam	Temporarily inundated	—	Unprotected
11	**Paarl WWTW**	**PA**	33°51S	18°40E	Sewage works	Permanently inundated	—	Unprotected
12	Rietvlei	Rv	33°50S	18°30E	Freshwater pans	Temporarily inundated	—	Partially protected
13	Diep River Estuary	dp	33°53S	18°29E	Estuary	Temporarily open	Cold temperate	Unprotected
14	Wildevoelvlei	Wv	34°08S	18°21E	Coastal lake	Permanently inundated	—	Unprotected
15	Zandvlei River Estuary	Zv	34°05S	18°28E	Estuary	Temporarily open	Warm temperate	Partially protected
16	Rondevlei	Rn	34°03S	18°29E	Coastal lake	Permanently inundated	—	Protected
17	Strandfontein WWTW	St	34°04S	18°30E	Sewage works	Permanently inundated	—	Unprotected
18	Macasser WWTW	Mc	34°04S	18°46E	Sewage works	Permanently inundated	—	Unprotected
19	Theewaterskloof Dam	Ve	34°24S	19°13E	State dam	Permanently inundated	—	Unprotected
20	**Bot River Estuary**	**BT**	34°13S	19°20E	Estuary	Temporarily open	Warm temperate	Partially protected
21	Klein River Estuary	kl	34°25S	19°55E	Estuary	Temporarily open	Warm temperate	Partially protected
22	De Mond Estuary	dm	34°42S	20°06E	Estuary	Temporarily open	Warm temperate	Unprotected
23	**De Hoop Vlei**	**DH**	34°38S	20°19E	Coastal lake	Temporarily inundated	—	Protected
24	Breede River Estuary	br	34°24S	20°48E	Estuary	Permanently open	Warm temperate	Unprotected
25	Great Brak Estuary	gb	34°03S	22°14E	Estuary	Temporarily open	Warm temperate	Unprotected
26	Wilderness Estuarine System	wt	33°59S	22°38E	Coastal lake	Temporarily open	Warm temperate	Partially protected
27	Swartvlei Estuarine System	th	33°59S	22°45E	Coastal lake	Temporarily open	Warm temperate	Partially protected
28	Knysna Lagoon	kn	34°03S	23°02E	Estuarine bay	Permanently open	Warm temperate	Unprotected
29	Keurbooms River Estuary	kb	34°01S	23°23E	Estuary	Permanently open	Warm temperate	Unprotected
30	Beaufort West WWTW	bw	32°22S	22°35E	Sewage works	Permanently inundated	—	Unprotected

[1] Site code used in correspondence analysis (Chapter 5); codes in caps are of the five focal sites to make them easily distinguishable for plotting purposes

[2] From Whitfield (2000)

Appendix 1.6 The Ramsar classification of wetlands (as provided on the Information Sheet for Ramsar wetlands, 2009-2012 version. (http://www.ramsar.org)

Marine/Coastal Wetlands

A	–	**Permanent shallow marine waters** in most cases less than six metres deep at low tide; includes sea bays and straits.
B	–	**Marine subtidal aquatic beds**; includes kelp beds, sea-grass beds, tropical marine meadows.
C	–	**Coral reefs**.
D	–	**Rocky marine shores**; includes rocky offshore islands, sea cliffs.
E	–	**Sand, shingle or pebble shores**; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks.
F	–	**Estuarine waters**; permanent water of estuaries and estuarine systems of deltas.
G	–	**Intertidal mud, sand or salt flats**.
H	–	**Intertidal marshes**; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes.
I	–	**Intertidal forested wetlands**; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests.
J	–	**Coastal brackish/saline lagoons**; brackish to saline lagoons with at least one relatively narrow connection to the sea.
K	–	**Coastal freshwater lagoons**; includes freshwater delta lagoons.
Zk(a)	–	**Karst and other subterranean hydrological systems**, marine/coastal

Inland Wetlands

L	–	**Permanent inland deltas**.
M	–	**Permanent rivers/streams/creeks**; includes waterfalls.
N	–	**Seasonal/intermittent/irregular rivers/streams/creeks**.
O	–	**Permanent freshwater lakes** (over 8 ha); includes large oxbow lakes.
P	–	**Seasonal/intermittent freshwater lakes** (over 8 ha); includes floodplain lakes.
Q	–	**Permanent saline/brackish/alkaline lakes**.
R	–	**Seasonal/intermittent saline/brackish/alkaline lakes and flats**.
Sp	–	**Permanent saline/brackish/alkaline marshes/pools**.
Ss	–	**Seasonal/intermittent saline/brackish/alkaline marshes/pools**.
Tp	–	**Permanent freshwater marshes/pools**; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.
Ts	–	**Seasonal/intermittent freshwater marshes/pools on inorganic soils**; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.
U	–	**Non-forested peatlands**; includes shrub or open bogs, swamps, fens.
Va	–	**Alpine wetlands**; includes alpine meadows, temporary waters from snowmelt.
Vt	–	**Tundra wetlands**; includes tundra pools, temporary waters from snowmelt.
W	–	**Shrub-dominated wetlands**; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.
Xf	–	**Freshwater, tree-dominated wetlands**; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.
Xp	–	**Forested peatlands**; peatswamp forests.
Y	–	**Freshwater springs; oases**.
Zg	–	**Geothermal wetlands**
Zk(b	–	**Karst and other subterranean hydrological systems**, inland

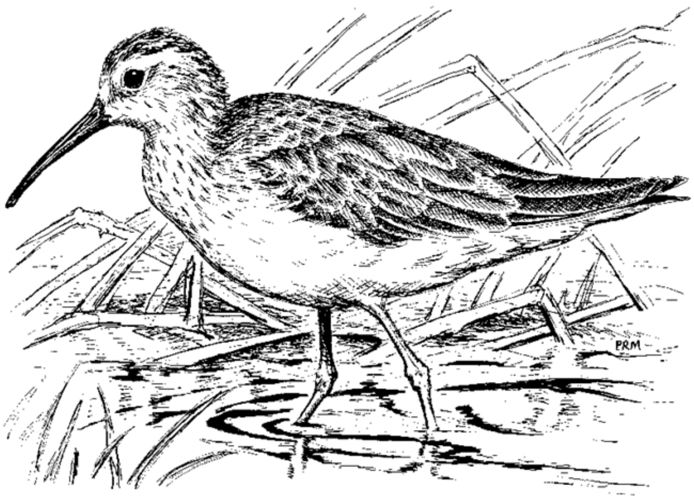
Human-made wetlands

1	–	**Aquaculture** (e.g., fish/shrimp) **ponds**
2	–	**Ponds**; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).
3	–	**Irrigated land**; includes irrigation channels and rice fields.
4	–	**Seasonally flooded agricultural land** (including intensively managed or grazed wet meadow or pasture).
5	–	**Salt exploitation sites**; salt pans, salines, etc.
6	–	**Water storage areas**; reservoirs/barrages/dams/impoundments (generally over 8 ha).
7	–	**Excavations**; gravel/brick/clay pits; borrow pits, mining pools.
8	–	**Wastewater treatment areas**; sewage farms, settling ponds, oxidation basins, etc.
9	–	**Canals and drainage channels, ditches.**
Zk(c)	–	**Karst and other subterranean hydrological systems**, human-made

Note: "**floodplain**" is a broad term used to refer to one or more wetland types, which may include examples from the R, Ss, Ts, W, Xf, Xp, or other wetland types. Some examples of floodplain wetlands are seasonally inundated grassland (including natural wet meadows), shrublands, woodlands and forests. Floodplain wetlands are not listed as a specific wetland type herein.

Chapter 2

The Waterbird Conservation Value score: a new method to assess wetland avifaunal importance



Abstract

Various analytical methods (species richness, species diversity, total count, biomass and energy consumption) have been used to assess the importance of wetlands for waterbirds. Although these are important indicators, they are limited in describing the real conservation value of the wetland for waterbirds. Traditionally, designation of wetlands of international importance (Ramsar sites) based on waterbirds has focused on those species meeting the Ramsar 1% population threshold levels. These levels, applied at global or sub-regional levels, prioritise a subset of species as being important with little or no consideration to the contributions of the remaining species' populations. In this chapter, I describe and discuss a new method to assess wetland avifaunal importance. Termed the Waterbird Conservation Value (WCV) score, this method calculates the ratio of each species' abundance to its known 1% threshold level and summed across all species to give a an overall waterbird conservation score. Larger score values indicate greater conservation value. There is a clear relationship between numbers of 1% threshold species and larger WCV scores but levels of species abundance determine the impact on the WCV score. Scores can be evaluated at site and species levels. Relative contributions made by all species are thus considered in the assessment and not limited to the Ramar 1% threshold species. The outputs of the WCV score are demonstrated using a case study from three regions within the East-Atlantic flyway.

Introduction

Assessing the value and importance of biological communities plays a critical role in conservation planning and management (Spellerberg 1981, Begon et al. 1990, Sutherland et al. 2004). Knowing the functions and status of organisms in ecosystems places value on sites and habitats and these have significance in determining the importance of the availability and distribution of habitats and sites for species (Ando et al. 1998). The ecological requirements vary between species so that habitats or sites become important or valuable for different species at different times throughout their annual cycle (Weller 1988, Tucker and Evans 1997).

From a conservation perspective, the importance of a site is measured or gauged based on site characteristics and the intrinsic value of the species' populations at that site. Assessing these attributes assigns a value to the site and species present. Consequently, one can ask not only how important a site is for a species or a suite of species (i.e. spatial component), but also how important is a species or species' population at site (or local), regional or global levels (i.e. numerical component). There is inter-play between these two aspects so that an individual site can have greater conservation relevance to a single species compared with the actual abundance of a species.

A variety of studies has used varying methodologies to assess the biological, ecological or ornithological importance of a site. Goldsmith (1975) proposed a single index system to assess and prioritise ecological quality for different land-use patterns in the United Kingdom which considered criteria such as area, naturalness, richness and diversity. Gehlbach (1975) proposed a scoring system based on quantitative values for climax condition, educational suitability, species significance, community representation and human impact to prioritize natural areas in Texas, USA. Adamus and Clough (1978) considered 13 characteristics in evaluating the importance of species in natural areas in Maine, USA; the key ones were spatial distribution, area size needs, endemicity, scarcity and habitat specialisation. They highlighted the need for a ranking or weighted system to refine criteria important to site and species conservation. In The Netherlands, van der Ploeg and Vlijm (1978) evaluated procedures and usefulness of ecological methodologies for nature conservation and land use planning. Their assessment highlighted that ecological site evaluation ecological criteria and land-use types need to be weighted to prioritize conservation efforts.

Fuller (1980) attributed three aspects to classify sites of ornithological interest in the United Kingdom: population size, rarity and diversity. Using quantitative information, he assessed each attribute at local, county, regional, national and international level and assigned a rank for each attribute for each level; this provided a way to prioritise sites at different spatial scales. Spellerberg (1981) differentiated between ecological evaluation of a species and habitat evaluation. The former focuses entirely on the status of a species (e.g. how common or rare it is) and considers the degree of threat experienced by that species, while evaluating habitats is more complex and focuses on determining priority ranking of natural areas based on a range of habitats. Determining minimum population sizes and land area requirements for threatened species were the focus of Schaffer's (1981) species conservation review while Carter et al. (2000) determined the conservation priorities of North American songbird species using seven parameters namely relative abundance, area abundance, spatial extent of breeding and non-breeding distribution and threat indicators. They identified a 'watch list' for the USA based on a summation of parameter scores as a way to highlight species in urgent need of conservation attention. Finer spatial scale studies have also been undertaken to determine conservation priorities for specific species (e.g. Fischer and Lindenmayer 2002, McCann et al. 2007).

During the mid-1980s, BirdLife International launched its Important Bird Area (IBA) programme (http://birdlife.org/action/science/sites/index.html). This programme designates and defines areas that are important for birds based on the occurrence and/or population size of the following: globally threatened species, nationally threatened species, range restricted species, biome-restricted species and/or congregatory species; the latter group applies more regularly to waterbirds than terrestrial species. The first IBA directory was published for Europe (Grimmett and Jones 1989) followed by the Middle-East (Evans 1994) and Southern Africa (Barnes 1998). An extension of the IBA programme has been the identification of globally important Endemic Bird Areas (Stattersfield et al. 1998). A total of 218 EBAs have been designated worldwide and these focus mainly on range-restricted species. Although these areas have high conservation priorities for species with limited ranges most of them constitute passerine species with few waterbirds included. This makes ecological sense due to the fact that waterbirds are highly mobile, often migratory organisms, often not limited to specific wetlands for the most part of their annual cycle and able to move between sites when conditions become unfavourable. Although IBAs and EBAs are providing opportunities to identify and conserve areas for a wide-range of largely terrestrial species, there seems to be limited value of these programmes for long-term waterbird conservation.

Waterbirds and wetlands have been well studied in Western Eurasia and Africa over the past 40–50 years, but site conservation for waterbirds has been an ongoing challenge (Beintema and van Essen 1999, Davidson and Stroud 2006). Concern for waterfowl populations and wetland habitats were first raised in the late 1930s and this led to an International Wildfowl Inquiry being set up (Kuijken 2006). This group formulated initiatives to assess the reasons for the worldwide decline of waterfowl populations and loss of related wetland habitats, and determine protective measures to put in pace. In 1954 the International Waterfowl and Wetlands Research Bureau was established and in 1967 the first formal research and monitoring programme was introduced – the International Waterbird Census (initially called the International Wildfowl Census). In 1971, the Convention on the Conservation of Wetlands of International Importance (commonly referred to as the Ramsar Convention) was established and the 1% criterion was adopted as a tool in ecological evaluations specifically to identify wetlands of international importance for waterbirds. The 1% criterion is discussed in more detail below. Recently programmes such as Wings Over Wetlands (Barnard et al. 2010, http://www.wingsoverwetlands.org) have provided additional conservation approaches to promote species and site conservation for migratory waterbirds in the African-Eurasian flyway.

In this chapter I identify and discuss the various ways of assessing avifaunal importance at site level, bearing waterbirds in mind. I then describe a new method to assess the conservation value of wetlands for waterbirds within the flyway framework and discuss the value of this method as a tool to develop better priorities for waterbird conservation globally.

Assessing avifaunal importance at site level

In the context of this paper, a site may be thought of as a wetland. Wetlands are generally perceived as discrete sites, with clearly defined natural boundaries. Terrestrial sites may, or may not, have natural boundaries. Much of what follows can also be applied to terrestrial sites. Various ecological attributes have been used to attempt to define the avifaunal importance of a wetland. Attributes (a) to (e) are listed, and dismissed as being either simplistic or inappropriate.

Species richness and species diversity

The number of different species at a wetland provides a measure of species richness. The generally accepted convention is that the greater the number of species the greater the importance this places on the value of the wetland.

On its own species richness has limited value. This is because the wetland may support many different species but each with small numbers of individuals. Species richness is particularly misleading if it includes vagrant species which have only occurred rarely at the wetland. Species richness thus does not necessarily indicate that the wetland is ecologically important, either overall or for particular species. As a result species richness is frequently linked together with abundance values to provide an index of species diversity. The number of indices which attempt to measure species diversity is enormous and definitions of species diversity are unclear and ambiguous (MacArthur 1961, MacArthur 1964, Hurlbert 1971, Whittaker 1972, Peet 1974, Huston 1979); Simpson's diversity index (λ) and the Shannon diversity index (H′) are generally considered the most popular and are extensively used in ecological studies (Pielou 1966, Peet 1975, Begon et al. 1990, Magurran 2004). But even here definitions and applications differ based largely on underlying assumptions that need to be considered, such as that all species are considered to be equally different, that all individuals in a species class are considered equal, and that all individuals are distributed evenly through the community (Hendrickson and Ehrlich 1971, Whittaker 1972, Peet 1974, Begon et al. 1990). For waterbirds, these assumptions are rarely met; Götmark et al. (1986), evaluated λ and H′ using data from Swedish wetland bird surveys, and concluded that these indices are of little value in site evaluation and should not be used to rank sites of ornithological interest.

Peet (1974) explored the methods and value of measuring species diversity and concluded that multiple concepts tend to be evaluated under the title of diversity. He highlighted that the characteristics and responses of species diversity indices will change based on community structure and that this needed to be understood as a basis for their application. Huston (1979) attempted to explain species diversity based on non-equilibrium interactions of competing populations. Hurlbert (1971) and Bachman (1998) even dismissed the species as a valid unit to measure diversity and argued that it was an outdated or non-concept; Bachmann (1998) added that there is an increasing consensus that as a category, the species is an artificial construct and suggested molecular units as more appropriate 'measurements' of diversity.

Based on the above, it is evident that there are many theoretical and conceptual issues surrounding 'species diversity'. The resultant opposing views leads to ambiguity and uncertainty of which indices provides the better evaluation. I therefore disregard species richness and species diversity as appropriate methods for evaluating the importance of a wetland site for waterbirds.

(a) Species status

The number of species with an adverse conservation status at a wetland has regularly been used to determine the value and or importance of a wetland. Status here includes Red Data Book species (Stattersfield and Capper 2004, Barnes 2000), range-restricted species (IBAs, see Heath et al. 2000), biome-restricted species (IBAs, see Heath et al. 2000), endemic species and breeding endemics (for southern Africa, see Hockey et al.

2005). Although this does have conservation value it frequently applies to a small percentage of the number of species recorded at the wetland and the focus of conservation efforts are therefore geared specifically towards these 'special' species. The remaining species are generally considered as having no or little conservation value either at an individual species level or at the overall wetland level. Using species status as a final wetland evaluation tool is too simplistic because it usually considers a small subset of the entire waterbird community at a site and therefore not representative of all species present at the site.

(b) Abundance

The total number of individuals at a wetland is frequently used to provide a measure of the significance of a wetland. It is usually regarded that the larger the number of individuals at the site the greater the conservation value of the site. While this may have importance at a local/site level, from a regional or global population perspective the number of birds may have less significance.

The Convention on the Conservation of Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention) identifies, under Criterion 5, that a wetland should be considered as internationally important if it regularly supports 20 000 or more waterbirds. This criterion is simple to implement because it requires knowledge only of the number of birds counted at the site.

This criterion rarely applies to southern African wetlands; wetlands holding more than 20 000 waterbirds are rare in this region. Compared with temperate regions in the northern hemisphere, where permanent wetlands support predictable numbers of waterbirds (Cramp and Simmons 1977), most southern African wetlands are temporary and ephemeral, and waterbird occurrence thus unpredictable.

Although abundance on its own provides some indication of how important a site may be for waterbirds, there is usually a bias towards sites which support over-abundant species with less attention paid to sites which support less abundant sites (Rosa et al. 2003, Paracuellos and Telleria 2004, Bolduc and Afton 2008). In addition, the Ramsar 20 000 criterion cannot be adequately applied globally because of varying wetland types, particularly marine areas (Skov et al. 2007). Total abundance is therefore not a definitive method to evaluate wetland importance for waterbirds.

Another disadvantage of simple numerical abundance is that it takes no account of the size of the bird. These disadvantages are addressed in (d) and (e) below.

(c) Biomass

Biomass, also referred to as the standing crop, is defined as the mass of living biological organisms per unit area at a given time and can be expressed in units of energy (e.g. joules/m^2) or dry organic matter (tonnes ha^{-1}) (Begon et al. 1990). It is usually measured to give the natural mass of organisms *in situ*.

Although overall abundance (see above) represents a first quantitative measure of the importance of a wetland, biomass represents an alternative quantitative method to assess site importance. Measuring the importance of a wetland as the total number of waterbirds present makes the assumption that each individual of a species makes an equal contribution to the waterbird community, so that one Greater Flamingo *Phoenicopterus ruber* is equivalent to one Little Stint *Calidris minuta*. This has limitations in assessing wetland importance for waterbirds as larger and heavier species have a larger impact on the wetland than smaller birds. One alternative to using a simple total of the number of each species of waterbird is to compute the total biomass of all the birds. The composition of the waterbird community may be such that large numbers of smaller-sized (lighter) birds could represent the same biomass as a smaller number of larger-sized (heavier) birds. For example, at a given wetland 20 000 Little Stints (mean mass 20 g) would represent the same biomass as 115 Greater Flamingos (mean mass 3500 g). In the biomass calculation, each Greater Flamingo is equivalent to 175 Little Stints.

However, this is going to the opposite extreme. On the one hand, the abundance equation "one flamingo = one stint" is clearly unsatisfactory; on the other hand, the biomass equation "one flamingo = 175 stints" is also unsatisfactory, because we know that the metabolic rates of smaller birds are greater than those of heavier birds (Daan et al. 1990, Martin and Palumbi 1993, Gillooly et al. 2001). Thus an analysis based on biomass analyses will be biased in favour of the large species and an analysis based on numerical abundance will be biased in favour of the small species.

Ideally, what is needed is an index which measures the impact of each species on the wetland, effectively a measure of energy flow. However, I do not have measurements for each species; but we can estimate this from allometric equations, from which we know that energy is scaled as approximately mass to the power of two-thirds. This is the topic of the next section. Although the estimates of energy for individual species may differ from the allometric equation, the results obtained must be closer to the truth than either raw abundance or total biomass.

(d) Energy consumption

As argued above, energy, which is closely related to biomass, is a better way to assess the importance of a site is for waterbird communities. In ecological terms energy can be defined as ecological efficiency which is described as resource utilization and the extent to which resources are converted into biomass (Krebs 1999, Ricklefs and Miller 2000). Ecological efficiency, or how energy is transferred between different trophic levels, can be broken down into and quantified at various levels as described below:

- Exploitation efficiency is the amount of food ingested divided by the amount of prey production (I / P_n)
- Assimilation efficiency is the amount of assimilation divided by the amount of food ingestion (A / I)
- Net Production efficiency is the amount of consumer production divided by the amount of assimilation (P_{n+1} / A)
- Gross Production efficiency is the assimilation efficiency multiplied by the net production efficiency, which is equivalent to the amount of consumer production divided by amount of ingestion (P_{n+1} / I)
- Ecological efficiency is the exploitation efficiency multiplied by the assimilation efficiency multiplied by the net production efficiency, which is equivalent to the amount of consumer production divided by the amount of prey production (P_{n+1} / P_n)

Nagy (1987) investigated the allometric relationship between body mass M (g) and field metabolic rate (FMR, kJ/day) for different vertebrate groups. For birds, he estimated that the relationship is given by FMR = $10.9M^{0.640}$. An estimate of the Daily Energy Intake (DEI, kJ/day), including metabolized and non-metabolized energy, is then obtained by correcting the FMR for Assimilation Efficiency (AE, dimensionless): DEI=FMR/AE. Values of AE that are usually used for birds are 58% for herbivores (DEI=FMR/0.58) and 75% for invertebrate feeders and piscivores (DEI=FMR/0.75) (Velásquez et al. 1991, Ricklefs et al. 1996). The total DEI for a species is estimated as the product of the number of birds of the species and the DEI of the species. The overall DEI for the wetland is then estimated by summing the DEI values for all species occurring at the site. This value provides an estimate of total the amount of energy that the waterbird community extracts from the wetland.

On average, the DEI for one Greater Flamingo is 1373 kJ/day, and for one Little Stint is 63 kJ/day. Thus on the energy scale, one flamingo = 22 stints, compared with one flamingo = one little stint on the abundance scale and one flamingo = 175 stints on the mass scale. The allometric relationship thus suggests the 22 Little Stints have an impact on the wetland which is comparable to that of one Greater Flamingo.

Energy consumption is a useful tool when assessing the importance of a site for a waterbird species because it represents a common currency that facilitates inter-species comparisons. It also represents a valuable method for comparing wetlands because the importance of a wetland for waterbirds can be measured as an estimate of the total amount of energy extracted from it by the waterbirds. Generally, there is a strong correlation between high productivity and increased waterbird abundance and richness (Berruti 1983, González-Solís et al. 1996, Hornung and Foote 2006). For discussions of the importance of wetlands based solely on numerical data, this approach based on estimates of energy consumption is recommended, because it reduces the counts to an ecologically meaningful quantity for comparisons between species at a site and between sites.

However, none of the criteria (a) to (e) discussed takes any account of the conservation status of the species occurring at a wetland. Thus they do not adequately provide a measure for the overall importance of a wetland for waterbirds from a conservation perspective. They take no cognisance of the size of a population of a waterbird species at a wetland in relation to the overall population size. The rest of the chapter thus focuses on the following two criteria (f) the standard Ramsar 1% threshold and (g) a proposal for an extension to the standard assessment method, which I will describe as the Waterbird Conservation Value score.

(e) The 1% criterion

Counts of waterbirds at a wetland provide a measure of abundance for species present. But, as mentioned in (c) above, how significant that value is will be dependent on the knowledge of the proportion this count constitutes to the overall (global) or regional population for that species.

The concept of the 1% criterion was first introduced to waterbird ecology in 1971 at the inaugural meeting of the Ramsar Convention in Ramsar, Iran (Kuijken 2006). Prior to 1971, the International Waterfowl Research Bureau, (IWRB, predecessor of Wetlands International) had several meetings to consider the required level of waterbird numbers before a wetland could be considered as being of 'international importance'. After some debate and consideration of 5% and 2% models, the latter excluding a large number of critical network sites, particularly for migrant species, the 1% criterion was adopted (Kuijken 2006). The criterion (Criterion 6 of the Ramsar Convention) states that a wetland should be deemed internationally important if "it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird". This criterion has ever since been used to evaluate the ecological importance of wetlands for waterbirds on a global scale. Wetlands of International Importance (known colloquially as

“Ramsar sites”) have been designated based on this criterion and to date 1 953 wetlands have been registered under the Ramsar Convention covering 190 455 433 ha of the earth’s surface (http://www.ramsar.org). This criterion has also been used to designate Important Bird Areas (IBAs) in terms of BirdLife International’s IBA programme (Barnes 1998, Heath et al 2000, Fishpool and Evans 2001).

Application of the 1% criterion has been based on the waterbird databases held by the IWRB and and its successor Wetlands International. This covered the data submitted as part of the International Waterbird Census (IWC) initiated in 1967. Since 1995, Wetlands International has maintained the IWC databases and 1% thresholds are provided by Waterbird Population Estimates, a four-yearly publication published by Wetlands International, since 1994. The latest edition (Wetlands International 2006) contains the most up-to-date available population information for 2305 bio-geographical populations of 878 waterbird species; numerical abundance is provided for 79% of these populations.

The development and application of the 1% criterion considered a flyway approach to waterbird conservation, something that was not considered prior to the adoption of the Ramsar Convention. By far, this approach held the strongest conservation argument for identifying sites of conservation and flyway significance for many waterbird species.

However, the application of the Ramsar “1% criterion” is subject to considerable uncertainty. The 1% values themselves are generated by Wetlands International, and for many species they are based on educated guesses. But even if we accept these 1% threshold values, there are still question marks. Does a site meet the 1% threshold if this value is exceeded for a species on a single survey, or is it necessary for the mean (or median) of a series of counts of a species to exceed the threshold? Clearly, the latter is more convincing, because then the wetland regularly contains more the 1% of the population of a species that really does “want to be” at the wetland (as opposed to a potentially once off visitation).

However, from the perspective of the measure of wetland value to be proposed here, the key limitation with the Ramsar approach is its dichotomy. A species either meets the threshold at a wetland or does not meet it, and we are generally provided with a simple list of species meeting the threshold. Species just missing the threshold are disregarded. The Important Bird Area (IBA) site selection criteria, for southern Africa, recognised this flaw and created a third category of species, those that met the “half-percent criterion”, i.e. with between 0.5% and 1% of their population at the site.

All of the above attributes have significance at some or other level and used in conjunction they do provide a strong base for providing an assessment of the conservation importance of a site for waterbird populations. However, these criteria are usually considered in isolation, on a species by species basis, and although this provides valuable input, the overall consideration of all species is not taken into account, particularly with regards to the 1%, threshold levels. Bearing this in mind, I present an alternative way of assessing the importance of a wetland site for waterbirds. This is known as the Waterbird Conservation Score (WCS) and is defined below.

(f) The Waterbird Conservation Value score

The foundation of the Waterbird Conservation Value (WCV) score is based on the 1% threshold levels and the contribution each species makes to the overall population at a wetland. In principle the score is a measure of the proportion of each species' count relative to the global 1% threshold level for each species. The score is calculated by dividing the number of waterbirds of each species by the 1% threshold value of the species. This yields the number of 1% units of the species at the wetland. These values are then summed for all the species at the wetland to estimate the overall WCV score for the wetland. This can be represented by the following formula:

$$\text{WCV score} = \sum \frac{s_i}{R_t}$$

where

s_i = abundance of the species at a wetland

R_t = current Ramsar 1% threshold for the species s_i

Thus, if the WCV of a wetland is 45, then this is equivalent to having 45% of the entire population of a single (imaginary) species at the wetland. This approach to evaluating the 'value' of a wetland is more precisely nuanced than the crude method of counting the number of species that exceed the 1% thresholds. Because of the way that the WCV score is calculated, with the 1% threshold values in the denominators of a series of terms which are added, it is important that the 1% values are accurately estimated. If the threshold values are incorrect for a species which is abundant at a wetland, then the contribution of that species to the WCV score will either be biased large or biased small. If this system is adopted for assessing wetland importance, it increases the obligation on Wetlands International to estimate the 1% threshold as accurately as possible.

The underlying consideration is that each species makes a contribution to the WCV score, whether large or small. The overall score obtained represents a value which represents the importance of the combined conservation value of each species. Each individual bird makes a contribution to the WCV.

What values constitute a good or poor conservation score? This will depend on three inter-related factors: (1) the number of species recorded at the site, (2) the number of species reaching the 1% threshold and (3) the proportion values that each species makes to the total WCV score. Generally, large values for the WCV scores may be obtained in two ways: small contributions from a large number of species and large contributions from a few species. It is therefore difficult to interpret what constitutes a good or poor score as this will depend on the site or regions in which the waterbirds have been surveyed. This will be examined further in the case study described below. The hypothesis is that sites that support large numbers of birds with a high species richness will have high WCV scores.

Case study – East Atlantic Flyway

In order to test the application of the WCV score I gathered waterbird count data from wetland sites along the East-Atlantic Flyway (Figure 2.2). I chose three regions along this flyway: western Europe, West Africa and southern Africa. I selected the East Atlantic Flyway for three reasons: (1) it supports migrant waterbird populations that utilise the entire length of the flyway and which would lend itself to making comparisons between wetlands and regions; (2) there are well-established programmes of waterbird surveys at these wetlands, many with long-term datasets, within each section in the flyway and (3) the count data were readily available.

Methods

Waterbird census data were sourced from the International Waterbird Census database (Wetlands International unpubl. data), and the Coordinated Waterbird Counts (Animal Demography Unit unpubl. data) for sites within South Africa. Sites were grouped into three regions encompassing the flyway: Western Europe, West Africa and Southern Africa.

I selected January census data because this is the compulsory count period for the IWC which would ensure maximum availability to data. For logistical reasons, counts for some sites were not always carried out in January and were either undertaken in December or February (T. Langendoen *in litt.*). This three-month period was then identified as the 'January' count period which for the Northern Hemisphere would represent 'midwinter', while for the Southern Hemisphere this would be 'midsummer'. Mean counts for all species at all sites were extracted for the analysis. I restricted the analysis to wetlands for which the total number of waterbirds exceeded 20 000 and for those species which had defined 1% threshold levels (Wetlands International 2006); species which did not have defined levels or which occurred in small numbers were excluded. The data covered the period 1960–2011; however, the surveys at most wetlands spanned a shorter period. The frequency of counts varied across wetlands during this period.

Results

Totals of 137 sites were included from western Europe (comprising 105 species), 22 sites from western Africa (comprising 99 species), and 11 sites from southern Africa (comprising 65 species).

Summary statistics for each region are given in Tables 2.1 and 2.2. On average, western European sites had the smallest WCV scores (21.8), southern African sites the largest (77.0); West African sites had a mean WCV score of 59.2. For western Europe, WCV scores ranged from 1.7–205.5, for Western Africa 2.5–195.8 and for Southern Africa 4.1–174.2 (Table 2.1).

The relationship between the WCV score and the number of species reaching the 1% threshold for each region showed that there was a general trend towards sites that supported larger number of species reaching 1% threshold having large WCV scores (Figures 2.6a–2.6c). Although this was particularly notable in western Europe, there was large variation around this pattern. Across all three regions, sites with WCV values between 50–75 had a range of species from 2–16 reaching the 1% threshold.

In each region outliers were evident (Figures 2.6a–2.6c). In western Europe, two sites in the Waddenzee (MON01 and SEA01) had high WCV scores but were separated due to the number of species meeting threshold levels (Figure 2.6a). SEA01 had a single species (Common Eider) meeting 1% threshold and which contributed 100% to the site's WCV score (124.4), while MON01 had a higher WCV score (205.5) but had 16 species meeting Ramsar threshold levels (Appendix 2.1). Of the 16 species, three species constituted 60% to the overall score – Dunlin (80.4%), Bar-tailed Godwit (21.3) and Eurasian Curlew (19.9).

Three sites in western Africa (Waza Lagoon, Lac Tchad/Nigeria and Mare de Albarkaize) revealed WCV scores greater than 100 but with five or fewer species meeting 1% threshold levels (Appendix 2.2). Waza Lagoon had the largest WCV score of 195.8, with Squacco Heron comprising 94% of the overall score, while Mare de Albarkaize had a score of 152.6 of which 140.6 comprised White-faced Duck and Fulvous Duck (Table 2.2, (Appendix 2.2). Lac Tchad/Nigeria scored 149.8, 87% of which comprised Squacco Heron. In contrast, Delta du Saloum National Park supported 26 Ramsar-threshold species and scored 131.3; the species making the greatest contributions were Slender-billed Gull (score = 33), Caspian Tern (26), Grey-headed Gull (8.6) and Little Stint (6.7).

In southern Africa, Walvis Bay had 21 species exceeding the 1% threshold, the largest of any wetland in the region. It has a large WCV score of 137.8; in contrast, Sua Pan had the largest WCV score (174.2) but only had two species which reached the 1% threshold (Appendix 2.3). Sua Pan was dominated by Lesser Flamingo (166.7) and to a lesser degree by Greater Flamingo (6.6), while five species comprised more than 50% of the WCV score at Walvis Bay: Chestnut-banded Plover (23.6), Greater Flamingo (20.1), Lesser Flamingo (18.2), Black-necked Grebe (15.1) and Pied Avocet (6.9). Three additional sites (Sandwich Harbour: Western Sandspit, Langebaan Lagoon and Swakopmund Saltworks) had WCV scores greater than 100 but with eight or fewer species reaching the 1% threshold (Table 2.2, Appendix 2.3).

A summary of the priority species (i.e. species showing large WCV scores) contributing to the overall WCV score in each flyway region is shown in Figure 2.7. Both mean and maximum scores are presented; for the latter a threshold value of 20 or more was used to indicate species making substantial contributions. Patterns of species' dominance were noted between each region. A shorebird–waterfowl grouping was evident in western Europe; on average Dunlin made the largest contribution followed by Northern Shoveler, Common Eider and Light-bellied Brent Goose. Interestingly Bar-tailed Godwit contributed to the overall maximum score but did not feature in the mean WCV score. In western Africa, a wader-waterfowl emerged as the dominat species grouping; Squacco Heron ranked first as the species making the largest contribution to the region's waterbird populations while White-faced Duck and Fulvous Duck made important contributions. A wader–shorebird grouping occurred in southern Africa dominated by Lesser Flamingo and Greater Flamingo; Black-winged Pratincole and Curlew Sandpiper made smaller, but important, contributions to the region's WCV score.

Discussion

In considering the outcomes from the relationships between the 1% threshold species and the WCV scores across the three regions in the flyway, it is evident that this places a new emphasis on the way in which waterbird population data are interpreted. The WCV score takes into account the entire waterbird assemblage and its relative contribution to global and/or regional species populations. It does not focus solely on the 1% threshold species, an approach that has largely been adopted in most waterbird studies to assess importance at a global level (e.g. Scott 1980, Pérez-Arteaga et al 2002, Anderson et al. 2003). The overriding concept of the WCV score is that each species makes a contribution to the waterbird populations at site level and that the cumulative score (or index) is therefore an improved representation of the overall waterbird conservation value of a site. This means that species that fall just short of the 1% threshold (e.g. WCV score of

0.99), would now make a contribution to the value of the site, whereas before they would have been excluded and been deemed unimportant. Notwithstanding this, it is important to note that species reaching the 1% threshold levels will tend to make larger contributions to the overall WCV score.

Regional variation in WCV scores

Why do the southern African sites have, on average, the largest WCV scores, bearing in mind that only 11 sites were assessed for this region; this was the number of sites supporting more than 20 000 waterbirds. The large WCV scores resulted mainly from the abundance of two species: Greater Flamingo and Lesser Flamingo (Table 2.2, Figure 3.7). All WCV scores for these species were high, particularly at the two sites in Botswana: Sua Pan and Sua Spit Natural Reserve. These sites represent two of three major breeding sites for these species in southern Africa (Williams and Velasquez 1997a, b). The large WCV scores for these two species resulted from the large counts during this period which resulted in larger proportions of birds relative to the estimated global population and this contributed to the large overall WCV score for this region. The Coefficient of Variation (CV) values showed that this region had relatively less variation in WCV scores across sites (Table 2.1). The reason for this is probably because waterbirds are less widespread and are concentrated at various permanent wetlands in the region.

For western Africa, high WCV scores for Squacco Heron from Waza Lagone Floodplain and Lac Tchad elevated the overall WCV score for this region (Table 2.2, Figure 2.7). There was substantial variability in the WCV scores for each site (Appendix 2.2) but, like southern Africa, this was considerably less than that for western Europe. In western Africa during January it is the peak of the dry season so waterbirds are congregated at sites which hold permanent water.

Western Europe, although it supported more sites, had the most variability (Table 2.1) in terms of the WCV score at any given site during January. Waterbirds are less evenly distributed in western Europe during January than western Africa and southern Africa due to greater availability of wetland sites across the region and a greater number of waterbird species. Three anatids (Common Eider, Northern Shoveler and Light-Bellied Brent Goose) had peak numbers during January (Table 2.2, Figure 2.7) which indicated its importance as a non-breeding refuge for these species; Dunlin was the only additional species with a mean WCV score above 1; this supports evidence that most of the populations for this species spend the non-breeding season in Western Europe (Delany et al. 2009, Figure 2.7).

The results of this case study showed that, on a flyway scale, the WCV scores provide a different perspective on the conservation value of a site than only considering the number of species which reached the 1% threshold. Based on this criterion, many sites appear to have limited conservation value because the importance of the site is based solely on the number of species attaining the threshold. In contrast, the WCV score has two advantages: (1) it considers all species, including those that do not reach the 1% threshold, and evaluates an overall cumulative conservation importance of all the species on the site; (2) for those species that exceed the 1% threshold it is sensitive to the amount by which the threshold is exceeded.

Conclusions and recommendations

The WCV score provides a rapid conservation assessment of a wetland based on the cumulative sum of 1% thresholds of the community of waterbird species at the wetland; this is a first attempt, since the implementation of the 1% levels at the Ramsar Convention in 1971 (Kuijken 2006) to reconsider methods of assessing the conservation value of waterbird populations at wetlands. This new 'index' is based on the average number of birds of each species present at a site. As such, it is a unidimensional criterion. Potential future extensions and developments could be multidimensional and also include, for example, the threat status of the species at the wetland, their taxonomic uniqueness, measures of the extent to which the species is dependent of the wetland at some stage in the annual cycle, etc. Under this scenario, a good strategy for evaluating the importance of a wetland is to use the techniques selected from Multiple Criterion Decisions Analysis, as undertaken by Mostert (2012) to prioritize species for conservation management action in terrestrial protected areas in South Africa.

In terms of the application of the WCV score in the broader conservation context, there is a need to consider its effective use in guiding wetland and waterbird assessments. As a tool to measure the conservation value of waterbird populations, it will be necessary to look at determining thresholds above which sites become regionally, nationally or internationally important. Results in this chapter showed that scores varied between sites, and between and within regions and based on large numbers of a single species or across multiple species. Although the score itself is a simple index, its' calculation is based on multiple criteria such as species composition, species abundance and set (known) 1% thresholds for each species, Linked to these are seasonal variations, changes in population demographics and survey frequencies. Combined, all these will impact on the site WCV score – scores may be higher in one month or season and lower in others. Ultimately scores will need to be determined based on the temporal survey data available. Consequently, determining thresholds may not be a simple task. However, a score of 25 or more is proposed as a preliminary threshold above which sites could be deemed to be internationally important. This level would represent at least 25% of our single (imaginary) waterbird population (see above), which would represent a significant proportion of a 'species' global population. Sites scoring 100 or more could be deemed to be priority conservation sites. However, this threshold concept will need to be explored further in greater detail to fully understand the meaning of both the WCV score measure and deemed thresholds. This will be the case for national and regional thresholds which will depend on national or regional population estimates being available. Thus, some sites may well reach national or regional thresholds but fail to reach an international threshold. The identification of site thresholds and describing WCV scores as "poor" or "good" will ultimately assist managers, administrators and politicians in easily interpreting and understanding the importance of wetland sites for waterbirds and their conservation value for biodiversity.

It should be noted that the use of the WCV score should not be seen in isolation, rather it should be used as a tool that will complement the application of the Ramsar 1% thresholds. Adopting Multiple Criterion Decision Analysis (see above) techniques with additional in-depth exploration of the data should make valuable improvements to the WCV score and its application. A final recommendation, therefore, is that these aspects should be incorporated into the next phase of the development of the WCV score whereafter the score should thoroughly tested and reviewed before consideration as a new method to assess wetland and waterbird conservation status.

This chapter dealt with an introduction to the description and methodology of the WCV score and was based on a single set of averaged values per wetland. In Chapter 3, I explore further applications of the WCV score in the context where there is a time series of surveys at a single wetland. Here the score is applied to the individual surveys.

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Table 2.1 Comparison of Waterbird Conservation Value (WCV) scores from January waterbird surveys from three regions within the East Atlantic Flyway. Sites that supported more than 20 000 waterbirds are included in the analysis. Coefficient of Variation (CV) values and the number of sites with WCV scores above 50 are also given for each region.

Flyway region	No. of sites	No. of species	No. spp. reaching 1% threshold (%)	WCV score				
				Mean (± S.D.)	Median	Min.– Max.	CV	n ≥ 50
Western Europe	137	105	63 (60%)	21.8 (± 26.0)	13.4	1.7 –205.5	1.19	12 (9%)
Western Africa	22	99	62 (63%)	59.2 (± 54.5)	48.0	2.5 –195.8	0.91	9 (40%)
Southern Africa	11	65	29 (45%)	77.0 (± 54.8)	84.1	4.1 – 174.2	0.70	6 (55%)

Table 2.2 Mean and maximum WCV scores for 117 waterbird species within the three regions of the East Atlantic flyway. Species selected based on at least one site within in each region meeting the 1% threshold. See text for explanation and derivation of the WCV score. WE = western Europe, WA = western Africa and SA = southern Africa.

Species	Mean			Max.		
	WE	WA	SA	WE	WA	SA
African Black Oystercatcher	-	-	0.23	-	-	1.61
African Darter	-	0.15	-	-	1.83	-
African Purple Swamphen	-	0.76	-	-	13.30	-
African Pygmy Goose	-	0.08	-	-	1.23	-
African Skimmer	-	0.08	-	-	1.69	-
Audouin's Gull	-	0.17	-	-	2.85	-
Barnacle Goose	0.11	-	-	6.20	-	-
Bar-tailed Godwit	0.55	0.13	-	21.29	1.32	-
Bean Goose	0.14	-	-	14.50	-	-
Bewick's Swan	0.15	-	-	13.83	-	-
Black Heron	-	0.21	-	-	3.15	-
Black Stork	-	0.39	-	-	5.53	-
Black Tern	-	-	0.29	-	-	1.48
Black-crowned Crane	-	0.16	-	-	1.73	-
Black-crowned Night-heron	0.02	0.41	-	1.11	7.92	-
Black-headed Gull	0.21	-	-	2.87	-	-
Black-necked Grebe	-	-	1.83	-	-	15.10
Black-tailed Godwit	0.35	1.38	0.22	11.79	7.78	2.40
Black-winged Pratincole	-	-	9.53	-	-	104.79
Black-winged Stilt	0.06	0.84	0.38	1.72	6.56	1.71
Cape Cormorant	-	-	3.35	-	-	17.72
Caspian Tern	-	2.02	1.93	-	26.06	6.20
Cattle Egret	-	0.49	-	-	2.76	-
Chestnut-banded Sandplover	-	-	4.04	-	-	23.59
Comb Duck	-	0.43	-	-	2.72	-
Common Coot	0.23	-	-	1.66	-	-
Common Crane	0.13	-	-	14.73	-	-
Common Eider	1.78	-	-	124.36	-	-
Common Greenshank	-	0.07	-	-	1.04	-
Common Gull	0.07	-	-	1.30	-	-
Common Pochard	0.33	-	-	4.53	-	-
Common Pratincole	-	1.16	-	-	17.33	-
Common Redshank	0.20	0.11	-	3.20	1.61	-
Common Ringed Plover	-	0.87	-	-	5.03	-
Common Scoter	0.04	-	-	3.23	-	-
Common Shelduck	0.44	0.21	-	10.28	2.56	-
Common Teal	0.17	-	-	2.48	-	-
Common Tern	-	-	1.50	-	-	14.69
Crested Tern (Swift tern)	-	-	0.71	-	-	3.89
Curlew Sandpiper	-	0.25	3.44	-	2.18	15.67
Damara Tern	-	-	0.31	-	-	1.82
Dark-Bellied Brent Goose	0.40	-	-	14.11	-	-
Dunlin	4.89	0.23	-	80.41	3.02	-
Eurasian Curlew	0.33	-	-	19.90	-	-
Eurasian Golden Plover	0.12	-	-	1.61	-	-
Eurasian Oystercatcher	0.39	-	-	19.56	-	-
Eurasian Spoonbill	0.12	0.64	-	3.47	4.52	-
Eurasian Wigeon	0.18	0.49	-	1.78	6.18	-
Fulvous Duck	-	5.14	-	-	75.07	-
Gadwall	0.40	-	-	16.89	-	-
Garganey	-	1.59	-	-	11.7	-
Glossy Ibis	0.02	-	-	1.39	-	-
Goldeneye	0.08	-	-	1.56	-	-
Goosander	0.05	-	-	2.86	-	-
Great Cormorant	0.35	-	-	4.01	-	-
Great Crested Grebe	0.08	-	-	1.88	-	-
Great ringed Plover	0.13	-	-	3.00	-	-
Great White Pelican	-	1.42	1.60	-	19.35	7.81
Greater Flamingo	0.50	2.20	12.62	11.84	21.22	78.86
Greater Scaup	0.26	-	-	18.06	-	-
Greater White-fronted Goose	0.04	-	-	2.24	-	-
Grey Plover	0.19	0.26	0.48	4.18	2.15	3.73
Grey-headed Gull	-	0.52	-	-	8.56	-
Greylag Goose	0.27	0.13	-	9.37	1.52	-
Gull-billed Tern	-	0.21	-	-	1.79	-

Table 2.2 contd

Species	Mean			Max.		
	WE	WA	SA	WE	WA	SA
Hartlaub's Gull	-	-	0.68	-	-	2.27
Herring Gull	0.14	-	-	3.32	-	-
Kelp Gull	-	-	0.60	-	-	2.76
Kentish Plover	0.09	1.16	-	2.31	12.45	-
Kittlitz's Plover	-	-	0.62	-	-	3.63
Lesser Black-backed Gull	0.05	0.22	-	1.4	3.61	-
Lesser Crested Tern	-	-	0.10	-	-	1.12
Lesser Flamingo	-	2.55	23.31	-	45.03	166.67
Light-bellied Brent Goose	1.29	-	-	56.06	-	-
Little Egret	0.10	0.25	-	1.56	1.76	-
Little Stint	0.06	1.10	0.45	1.57	6.86	3.47
Little Tern	-	0.18	-	-	1.69	-
Mallard	0.24	-	-	1.84	-	-
Marbled Teal	0.02	-	-	1.38	-	-
Mute Swan	0.08	-	-	3.30	-	-
Northern Lapwing	0.13	-	-	2.09	-	-
Northern Pintail	0.79	0.87	-	11.25	10.17	-
Northern Shoveler	2.11	0.23	-	37.65	1.7	-
Pied Avocet	0.42	0.88	1.58	9.2	9.04	7.58
Pink-backed Pelican	-	0.11	-	-	2.14	-
Pink-footed Goose	0.21	-	-	7.83	-	-
Purple Heron	-	0.17	-	-	1.19	-
Purple Swamphen	0.12	-	-	5.33	-	-
Red Knot	0.54	0.07	-	12.6	1.23	-
Red-breasted Merganser	0.06	-	-	2.11	-	-
Red-crested Pochard	0.33	-	-	9.15	-	-
Red-knobbed Coot	-	0.11	-	-	1.61	-
Reed Cormorant	-	0.26	-	-	1.85	-
Royal Tern	-	0.17	-	-	2.79	-
Ruddy Turnstone	0.10	0.15	0.41	2.39	2.9	1.68
Ruff	-	0.99	-	-	15.25	-
Sanderling	0.09	0.20	2.33	2.18	2.13	14.12
Sandwich Tern	-	0.10	0.14	-	1.14	1.08
Senegal Thick-knee	-	0.13	-	-	2.10	-
Slender-billed Gull	-	1.54	-	-	33.07	-
Smew	0.07	-	-	3.95	-	-
Spotted Redshank	-	0.17	-	-	3.28	-
Spur-winged Goose	-	0.63	-	-	6.50	-
Squacco Heron	-	16.21	-	-	185.19	-
Temminck's Stint	0.01	-	-	1.62	-	-
Tufted Duck	0.18	-	-	2.68	-	-
Western Reef Egret	-	0.08	-	-	1.48	-
Western Yellow-legged Gull	0.06	-	-	1.81	-	-
Whiskered Tern	-	0.12	0.71	-	1.7	3.69
White Stork	-	0.06	-	-	1.01	-
White-breasted Cormorant	-	0.55	1.53	-	6.86	5.49
White-faced Duck	-	5.85	-	-	65.80	-
White-fronted Plover	-	0.14	1.21	-	2.35	-
White-fronted Plover	-	-	-	-	-	6.23
White-headed Duck	0.06	-	-	4.49	-	-
Whooper Swan	0.06	-	-	1.43	-	-
Yellow-legged Gull	0.05	-	-	1.18	-	-
Total	**21.30**	**58.44**	**76.12**	**648.86**	**705.15**	**520.86**

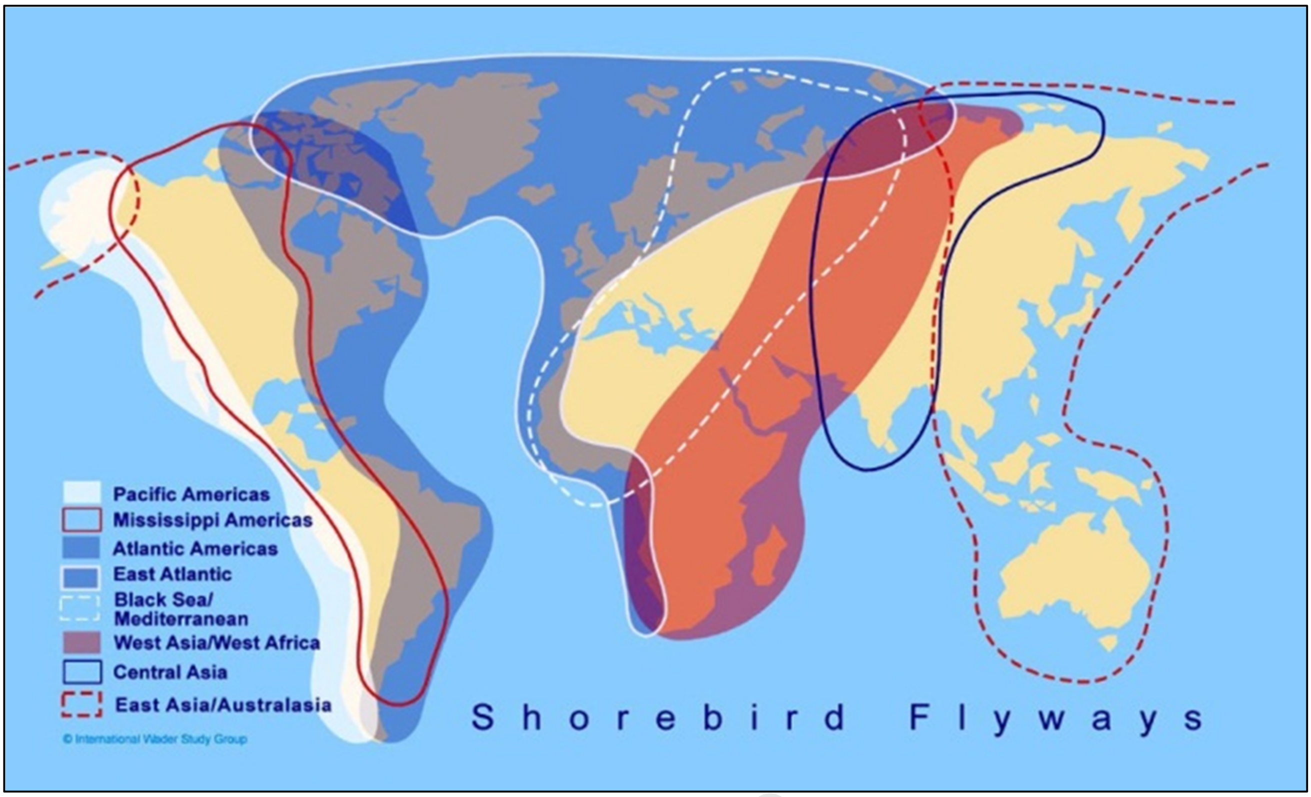


Figure 2.1 The extent of the eight major global bird migration flyways. The East-Atlantic flyway is shaded blue with a white border. (Map courtesy of International Wader Study Group)

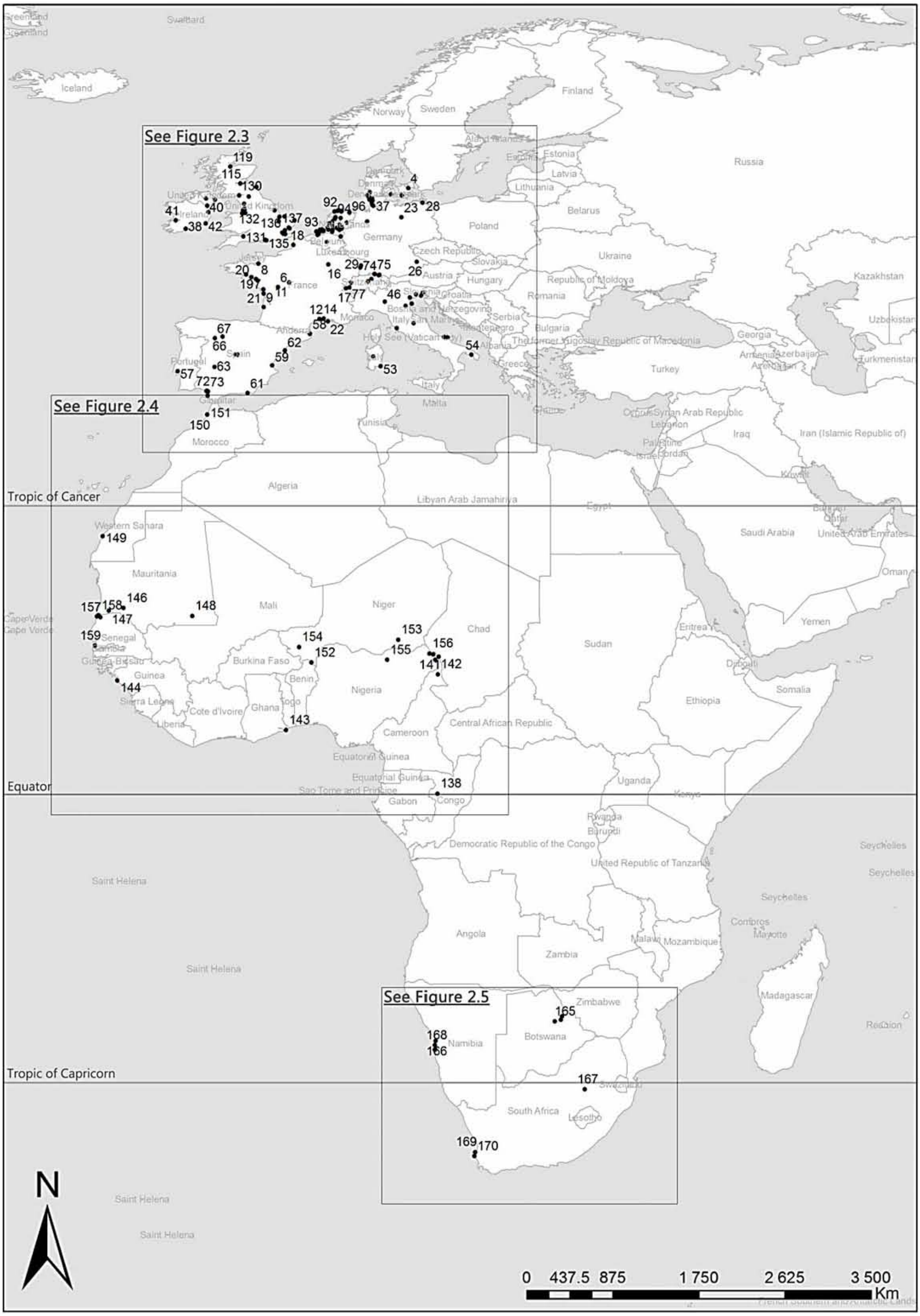


Figure 2.2 Locations of 170 wetland sites within the East Atlantic flyway used in the computation and comparison of WCV scores.

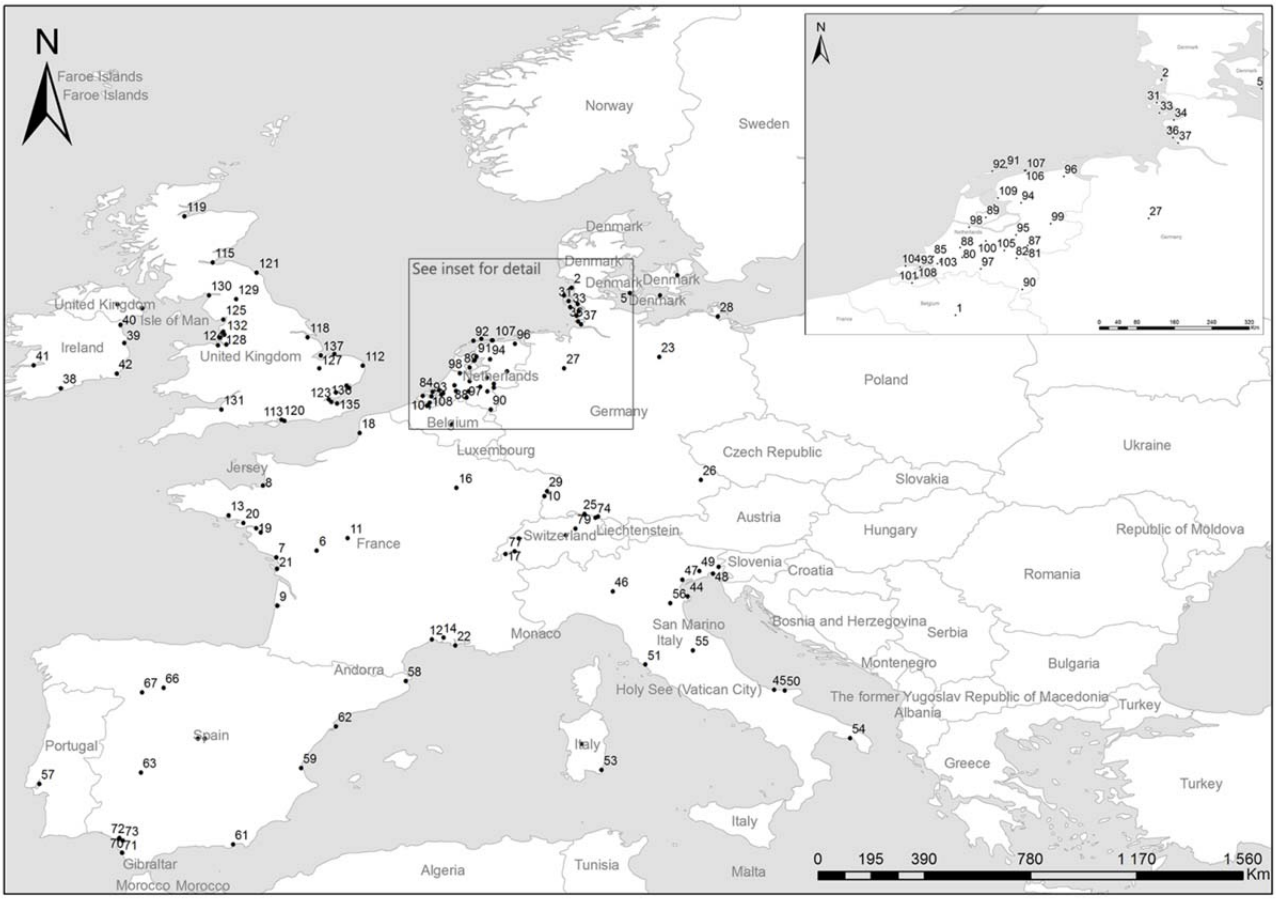


Figure 2.3 Locations of 137 wetland sites in western Europe used in the computation and comparison of WCV scores. Refer to Appendix 2.4 for names of the sites.

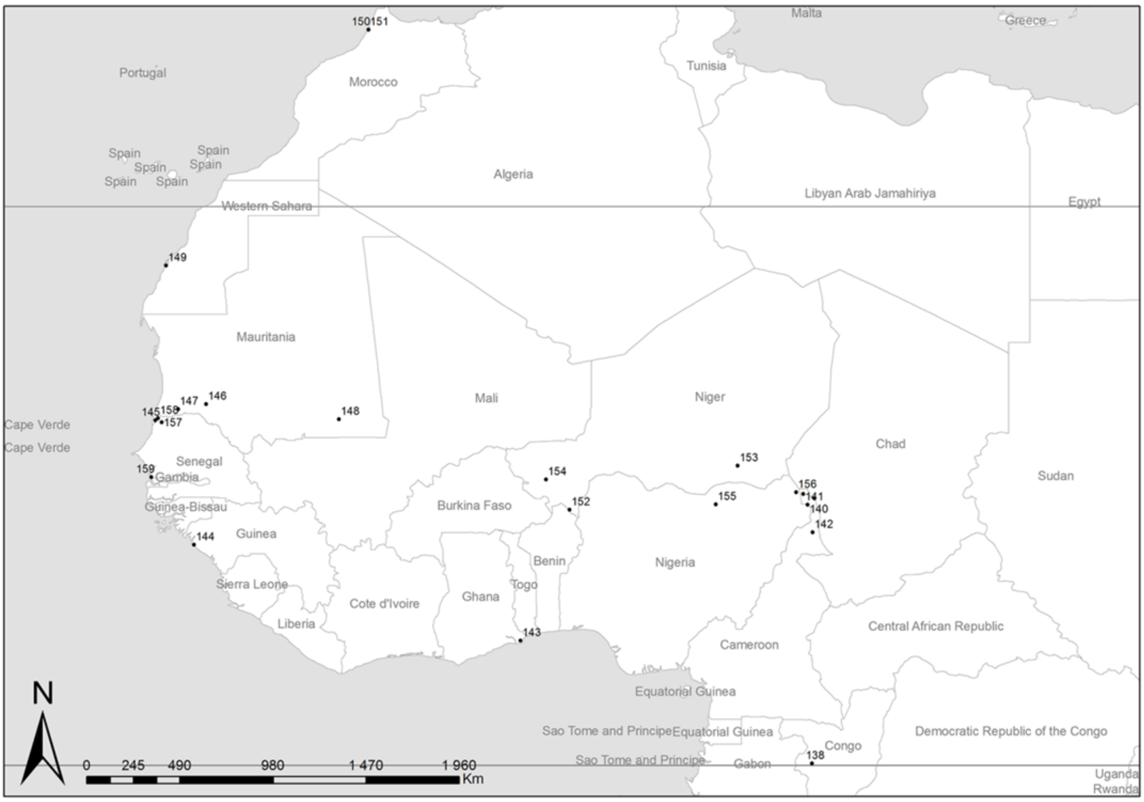


Figure 2.4 Locations of 22 wetland sites in western Africa used in the computation and comparison of WCV scores. Refer to Appendix 2.5 for names of the sites.

Figure 2.5 Locations of 11 wetland sites in southern Africa used in the computation and comparison of WCV scores. Refer to Appendix 2.6 for names of the sites.

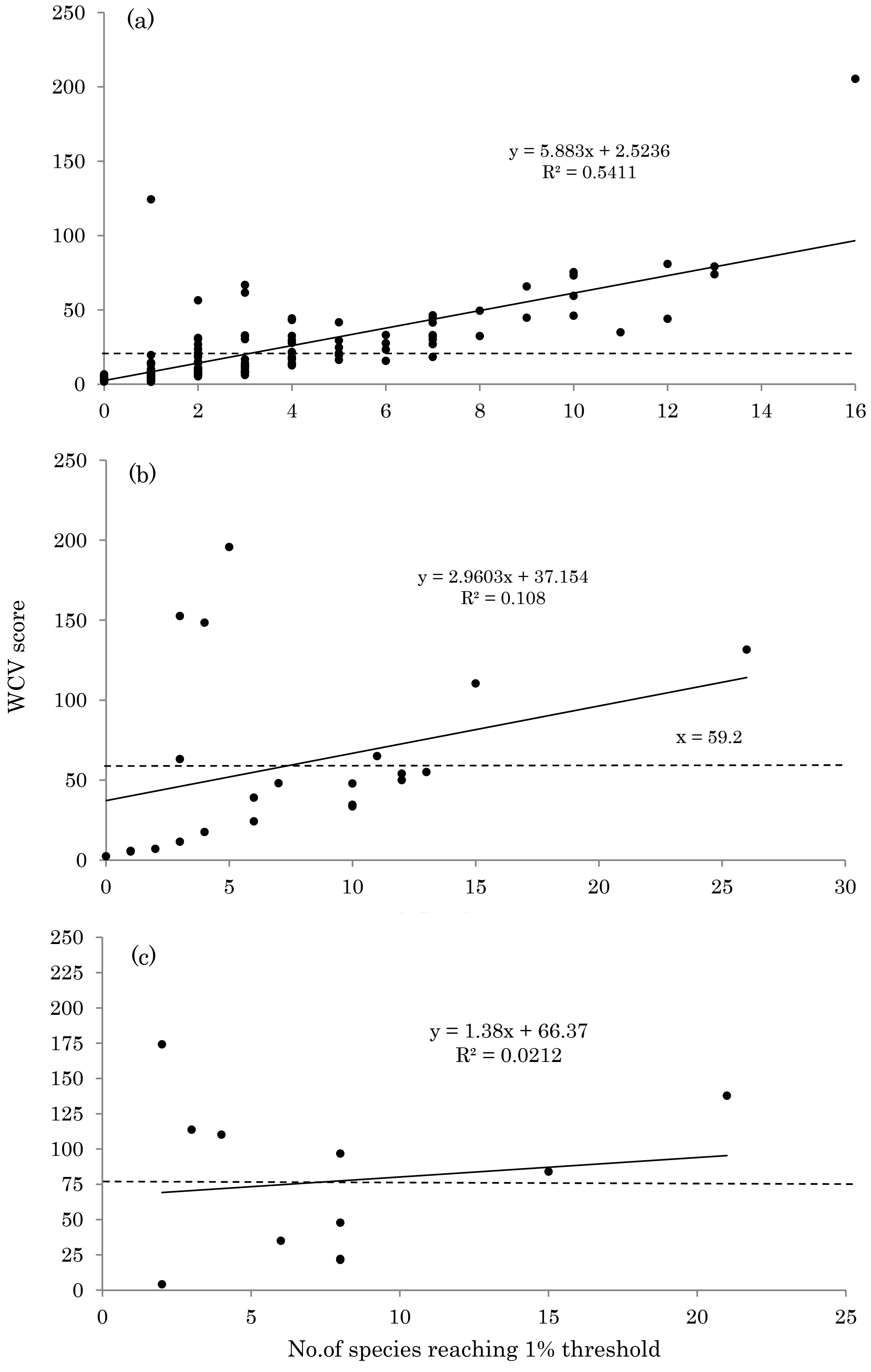


Figure 2.6 The relationship between the number of species reaching the 1% threshold and the Waterbird Conservation Value (WCV) score for (a) western Europe, (b) western Africa and (c) southern Africa. The dotted line represents the mean WCV score.

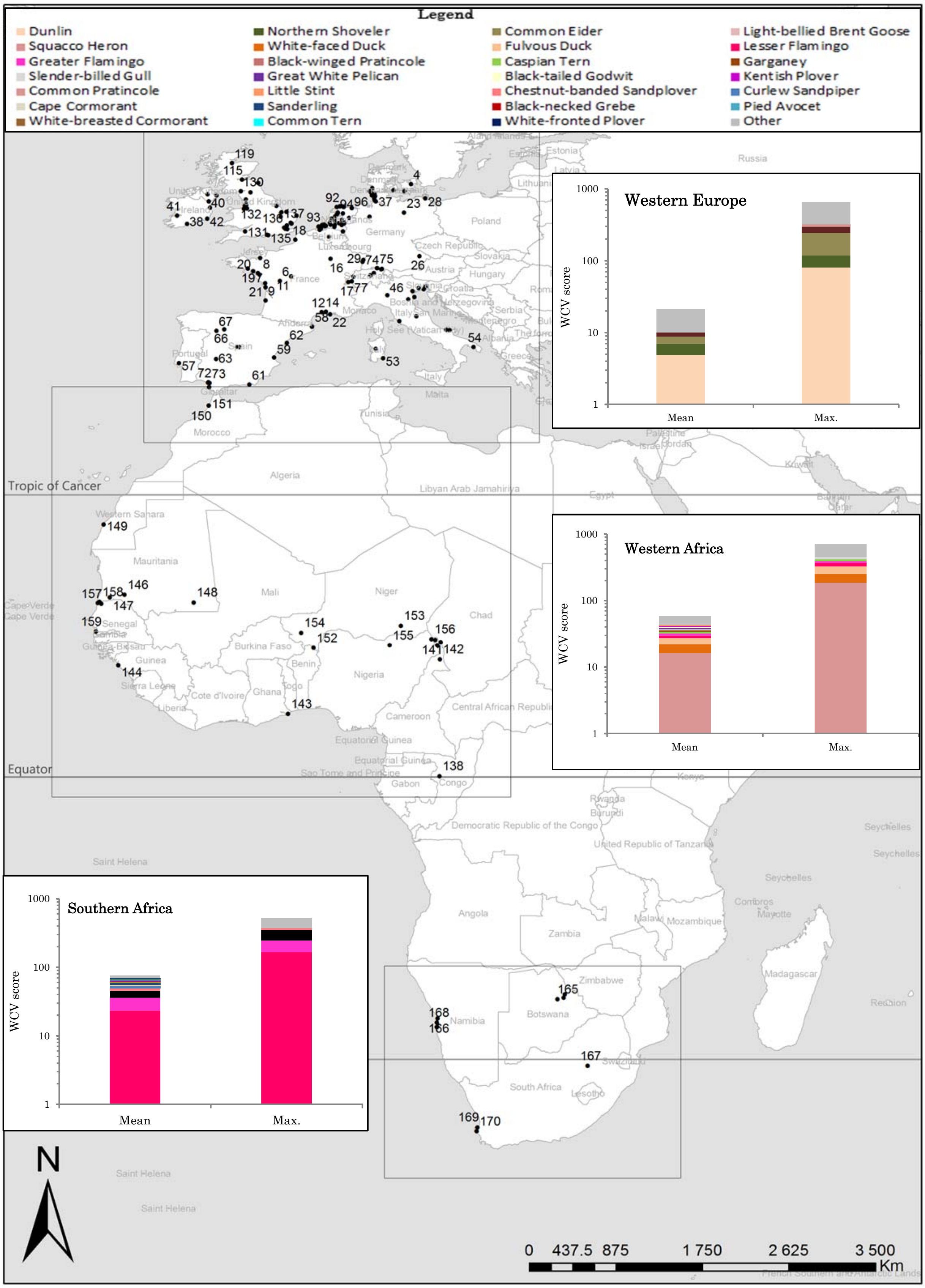


Figure 2.7 Comparison of mean and maximum WCV scores for priority species in western Europe, western Africa, and southern Africa. Species with mean WCV scores values ≥ 1 and maximum scores ≥ 20 are shown. Species colours are unique and used throughout the thesis. Values on y-axis given on logarithmic scale ($\log_{10}$).

Appendix 2.1 Matrix of mean Waterbird Conservation Value (WCV) scores for 137 sites and 105 waterbird species in western Europe during January. Data on which the scores are based were sourced from International Waterbird Census database, Wetlands International (T. Langedoen in litt.).

Species	Wetlands International Site Code																			
	ES00017	ES02188	GB00101	DE00116	ES00071	FR00088	IT00036	FR00109	FR00123	FR00139	NL00194	GB00525	CH00021	DE00262	CH00022	DE00263	GB00675	GB01020	IE00148	FR00167
Audouin's Gull	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barnacle Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bar-tailed Godwit	0.00	0.00	3.16	0.00	4.62	0.00	0.01	0.48	0.65	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.03	0.62	0.22	0.00
Bean Goose	0.00	0.00	0.00	14.50	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.00	0.00	0.00	2.32
Bewick's Swan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.59	0.04	0.02	0.02
Black-crowned Night-heron	0.00	0.09	0.00	0.00	1.11	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-headed Gull	0.45	1.25	0.08	0.00	0.06	0.01	0.20	0.00	2.87	0.27	0.05	0.02	0.18	0.39	0.07	0.18	0.29	0.08	0.11	0.11
Black-legged Kittiwake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Black-necked Grebe	0.01	0.01	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.04	0.00	0.00	0.01	0.03	0.02	0.04	0.00	0.00	0.00	0.00
Black-tailed Godwit	0.00	0.04	0.01	0.00	0.26	0.00	0.00	3.15	0.60	0.06	0.00	0.16	0.00	0.00	0.00	0.00	0.42	0.22	0.45	0.00
Black-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-winged Stilt	0.00	0.02	0.00	0.00	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caspian Gull	0.16	0.12	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caspian Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cattle Egret	0.49	0.68	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Coot	0.03	0.01	0.01	0.00	0.00	0.01	0.33	0.01	0.01	0.34	0.18	0.02	0.44	0.54	0.41	1.02	0.02	0.01	0.00	0.35
Common Crane	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.11	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Eider	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.04	0.01	0.00	0.06	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.01
Common Greenshank	0.00	0.01	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Common Gull	0.00	0.00	0.07	0.00	0.00	0.00	0.03	0.00	0.18	0.00	0.01	0.00	0.02	0.09	0.02	0.03	0.02	0.09	0.02	0.01
Common Pochard	0.02	0.27	0.02	0.00	0.00	0.01	0.12	0.01	0.01	0.06	0.26	0.03	0.81	1.40	2.33	1.98	0.00	0.00	0.01	1.66
Common Redshank	0.00	0.01	0.24	0.00	0.04	0.00	0.06	0.12	0.01	0.06	0.00	0.46	0.00	0.00	0.00	0.00	0.26	0.48	0.57	0.00
Common Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Scoter	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.11	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Shelduck	0.01	0.02	0.05	0.00	0.01	0.00	0.04	3.03	0.60	0.10	0.03	0.75	0.00	0.00	0.00	0.00	0.11	0.65	0.50	0.00
Common Snipe	0.02	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Common Teal	0.27	0.07	0.02	0.00	0.10	0.00	0.25	0.52	0.02	0.09	0.13	0.12	0.03	0.04	0.04	0.12	0.08	0.10	0.10	0.11
Curlew Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dark-Bellied Brent Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	1.31	14.11	0.00	3.17	0.00	0.00	0.00	0.00	0.02	3.82	0.01	0.00
Dunlin	0.03	0.23	1.09	0.00	6.17	0.00	0.58	15.08	19.94	38.29	0.01	9.78	0.00	0.00	0.00	0.00	2.16	12.46	4.52	0.00
Eurasian Bittern	0.03	0.00	0.00	0.00	0.00	0.02	0.09	0.00	0.00	0.02	0.06	0.03	0.02	0.00	0.02	0.02	0.00	0.00	0.00	0.02
Eurasian Curlew	0.02	0.00	0.09	0.00	0.00	0.00	0.10	0.20	0.61	0.37	0.02	0.23	0.02	0.01	0.01	0.03	0.15	0.23	0.26	0.00
Eurasian Golden Plover	0.11	0.02	0.03	0.00	0.09	0.54	0.00	0.09	0.16	0.00	0.02	0.34	0.00	0.00	0.00	0.00	0.88	0.14	0.35	0.00
Eurasian Oystercatcher	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.07	1.01	0.04	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.11	0.09	0.00
Eurasian Spoonbill	0.01	0.03	0.00	0.00	0.15	0.00	0.00	0.01	0.05	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eurasian Wigeon	0.02	0.05	0.00	0.00	0.02	0.00	0.65	0.33	0.11	0.08	0.00	0.17	0.00	0.00	0.00	0.01	0.40	0.08	0.12	0.06
Eurasian Woodcock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
European White-fronted Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Ferruginous Duck	0.05	0.12	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.03	0.03	0.00	0.03	0.04	0.08	0.09	0.00	0.00	0.00	0.05
Gadwall	0.25	0.17	0.01	0.00	0.00	0.02	0.66	0.08	0.01	0.13	0.00	0.08	0.45	0.40	0.68	1.98	0.07	0.04	0.01	5.52
Glossy Ibis	0.01	0.01	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goldeneye	0.00	0.00	0.01	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.05	0.06	0.14	0.55	0.38	0.18	0.00	0.01	0.00	0.21
Goosander	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.03	0.05	0.02	0.05	0.00	0.01	0.00	0.11
Great Black-backed Gull	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.04	0.00	0.01	0.00
Great Cormorant	0.20	2.16	0.25	0.01	0.73	0.04	0.20	0.06	0.03	0.41	0.38	0.13	0.07	0.15	0.08	0.12	0.08	0.03	0.23	1.21
Great Crested Grebe	0.01	0.01	0.00	0.05	0.00	0.00	0.06	0.00	0.00	0.01	0.08	0.01	0.12	0.23	0.25	0.13	0.00	0.00	0.04	0.15
Great Northern Diver	0.03	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.15	0.02	0.04	0.02	0.02	0.00	0.02	0.00	0.05	0.04	0.04
Great Ringed Plover	0.00	0.03	0.09	0.00	1.74	0.00	0.00	0.13	0.29	0.34	0.00	0.18	0.00	0.00	0.00	0.00	0.10	0.39	0.04	0.00
Great White Egret	0.00	0.02	0.00	0.00	0.00	0.03	0.14	0.00	0.00	0.07	0.02	0.00	0.01	0.01	0.01	0.04	0.00	0.00	0.03	0.07
Greater Flamingo	0.02	0.02	0.00	0.00	0.82	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Greater Scaup	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Greater White-fronted Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green Sandpiper	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grey Heron	0.01	0.44	0.00	0.00	0.16	0.01	0.04	0.00	0.01	0.04	0.03	0.01	0.02	0.02	0.01	0.02	0.00	0.01	0.02	0.05
Grey Plover	0.00	0.02	0.25	0.00	0.03	0.00	0.01	0.78	1.11	0.31	0.00	0.58	0.00	0.00	0.00	0.00	0.02	0.46	0.02	0.00
Greylag Goose	0.01	0.00	0.00	0.00	0.15	0.00	0.07	0.45	0.01	0.02	0.00	0.03	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.08
Herring Gull	0.01	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.22	0.49	0.00	0.01	0.00	0.00	0.00	0.00	0.04	0.00	0.01	0.00
Kentish Plover	0.01	0.04	0.00	0.00	1.35	0.00	0.06	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lesser Black-backed Gull	0.00	0.21	0.06	0.00	1.33	0.00	0.00	0.00	0.00	0.27	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
Light-bellied Brent Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.02	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.07	0.22	0.00
Little Egret	0.02	1.56	0.00	0.00	1.30	0.00	0.12	0.00	0.04	0.73	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.00
Little Grebe	0.01	0.01	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.02	0.01	0.01	0.02	0.03	0.14	0.05	0.00	0.01	0.01	0.12
Little Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little Ringed Plover	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little Stint	0.01	0.02	0.00	0.00	0.80	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long-tailed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mallard	0.44	0.35	0.02	0.06	0.03	0.02	0.29	0.36	0.14	0.02	0.35	0.03	0.12	0.32	0.08	0.16	0.01	0.02	0.02	1.05
Marbled Teal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mediterranean Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Moorhen	0.10	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mute Swan	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.01	0.00	0.21	0.00	0.03	0.04	0.15	0.11	0.22	0.04	0.03	0.01	0.45
Northern Lapwing	0.33	0.06	0.02	0.00	0.15	2.09	0.01	0.13	0.16	0.01	0.05	0.20	0.00	0.00	0.00	0.00	0.63	0.10	0.25	0.00
Northern Pintail	0.06	0.84	0.01	0.00	3.60	0.00	0.25	7.07	0.13	1.68	0.38	0.26	0.04	0.01	0.05	0.34	0.25	0.19	0.06	0.05
Northern Shoveler	1.77	23.01	0.01	0.00	9.99	0.05	0.53	3.39	0.14	0.59	0.49	0.10	0.10	0.11	0.02	0.58	0.46	0.02	0.17	0.13
Pied Avocet	0.01	0.06	0.00	0.00	1.87	0.00	0.00	6.68	0.07	0.15	0.00	0.15	0.00	0.00	0.00	0.00	0.12	0.01	0.00	0.00
Pink-footed Goose	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.44	0.00	0.00	0.00
Purple Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple Swamphen	0.23	0.08	0.00	0.00	4.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red Knot	0.00	0.00	2.30	0.00	0.00	0.00	0.00	1.16	1.18	0.01	0.00	0.28	0.00	0.00	0.00	0.00	0.08	0.16	0.02	0.00
Red-breasted Merganser	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.01	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.00
Red-crested Pochard	0.00	9.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.11	0.05	4.51	0.00	0.00	0.00	0.03
Red-necked Grebe	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Red-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ruddy Turnstone	0.00	0.00	0.11	0.00	0.00	0.00	0.01	0.12	0.05	0.38	0.00	0.28	0.00	0.00	0.00	0.00	0.01	0.11	0.08	0.00
Ruff	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanderling	0.00	0.06	0.40	0.00	0.01	0.00	0.01	0.17	0.23	0.07	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.07	0.00	0.00
Shag	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slavonian Grebe	0.00	0.00	0.03	0.00	0.00	0.00	0.07	0.06	0.03	0.12	0.00	0.26	0.04	0.05	0.03	0.04	0.00	0.11	0.06	0.04
Slender-billed Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smew	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.14	0.01	0.01	0.02	0.01	0.03	0.01	0.01	0.00	0.06
Spotted Redshank	0.01	0.05	0.00	0.00	0.28	0.00	0.01	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stone Curlew	0.09	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Taiga Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
Temminck's Stint	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tufted Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.47	0.01	0.35	1.08	1.26	0.90	0.00	0.00	0.00	1.36
Tundra Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28
Velvet Scoter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Rail	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Western Yellow-legged Gull	0.53	0.25	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.01	0.00	0.00	0.00	0.00
Whimbrel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whiskered Tern	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White Stork	0.05	0.00	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
White-headed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whooper Swan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.11	0.03	0.13	0.01	0.00	0.02	0.02
Yellow-legged Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
No. species at 1% level	**1.00**	**5.00**	**3.00**	**1.00**	**12.00**	**1.00**	**0.00**	**7.00**	**6.00**	**3.00**	**0.00**	**2.00**	**0.00**	**2.00**	**2.00**	**4.00**	**2.00**	**2.00**	**1.00**	**6.00**
Total WCV score	**6.02**	**41.73**	**9.08**	**14.64**	**44.10**	**2.90**	**6.78**	**44.64**	**33.18**	**61.63**	**3.39**	**18.57**	**3.65**	**6.06**	**6.27**	**13.07**	**10.00**	**21.16**	**8.86**	**15.79**

Appendix 2.1 contd

Species	Wetlands International Site Code																			
	DE00431	DK00047	ES00642	GB01364	ES00652	IT00137	DE00390	IE00192	IE00195	ES01154	PT00063	FR00212	FR00258	GB01817	NL00141	NL00154	NL00155	FR00266	ES01453	DE00785
Audouin's Gull	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barnacle Goose	1.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bar-tailed Godwit	1.26	0.00	1.53	0.12	0.00	0.00	1.01	0.00	1.26	0.00	0.64	0.00	0.00	0.73	0.00	0.00	0.00	0.03	0.00	0.00
Bean Goose	0.01	0.00	0.00	0.00	0.04	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83
Bewick's Swan	0.43	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-crowned Night-heron	0.00	0.00	0.00	0.43	0.37	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-headed Gull	0.07	0.01	0.09	0.00	0.63	0.00	0.15	0.01	0.12	0.02	0.02	0.05	1.60	0.15	0.42	1.07	0.30	0.41	2.39	0.00
Black-legged Kittiwake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-necked Grebe	0.00	0.00	0.00	0.10	0.70	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.41	0.00	0.00
Black-tailed Godwit	0.00	4.62	0.74	2.25	0.01	0.00	0.21	0.00	0.61	0.00	11.79	0.00	0.00	0.03	0.00	0.00	0.00	0.41	0.00	0.00
Black-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-winged Stilt	0.00	0.84	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Caspian Gull	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caspian Tern	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cattle Egret	0.00	0.01	0.00	0.97	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.02	0.07	0.00	0.00	0.00	0.00	0.01	0.37	0.00
Common Coot	0.00	0.08	0.01	0.93	0.68	0.20	0.00	0.00	0.00	0.02	0.01	0.14	0.22	0.00	0.41	0.38	0.42	0.27	0.00	0.04
Common Crane	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Eider	39.25	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	4.89	0.00	0.00	0.00	0.00	0.00	0.00
Common Greenshank	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Gull	0.68	0.00	0.04	0.00	0.01	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.03	0.06	0.20	0.09	0.07	0.00	0.00
Common Pochard	0.01	0.13	0.01	0.39	0.30	0.50	0.00	0.13	0.00	0.09	0.01	0.70	0.20	0.12	0.43	0.42	0.26	0.26	0.33	0.00
Common Redshank	0.21	0.03	1.41	0.35	0.02	0.00	0.44	0.00	0.36	0.01	0.61	0.01	0.01	1.13	0.00	0.00	0.00	0.11	0.00	0.00
Common Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Scoter	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.01	0.00	0.00
Common Shelduck	4.18	0.01	0.63	0.21	0.27	0.00	0.36	0.00	0.15	0.01	0.01	0.00	0.26	0.39	0.01	0.00	0.00	0.61	0.00	0.00
Common Snipe	0.00	0.01	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Common Teal	0.02	1.39	0.20	0.70	0.18	0.01	0.07	0.02	0.05	1.25	0.45	0.12	0.07	0.09	0.04	0.02	0.01	0.19	0.01	0.00
Curlew Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dark-Bellied Brent Goose	0.30	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00
Dunlin	14.22	1.12	15.01	14.38	4.76	0.00	3.31	0.00	4.44	0.00	10.33	0.08	0.35	5.17	0.00	0.00	0.00	18.10	0.00	0.00
Eurasian Bittern	0.00	0.00	0.00	0.07	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.02	0.04	0.02	0.00	0.00	0.00
Eurasian Curlew	0.47	0.00	0.46	0.05	0.06	0.00	0.16	0.00	0.17	0.00	0.09	0.01	0.00	0.36	0.13	0.02	0.11	0.08	0.00	0.00
Eurasian Golden Plover	0.27	0.00	0.02	0.21	0.01	0.00	0.07	0.00	0.51	0.00	0.04	0.05	0.02	0.10	0.00	0.00	0.00	0.01	0.00	0.00
Eurasian Oystercatcher	2.26	0.00	1.86	0.00	0.00	0.00	0.22	0.00	0.59	0.00	0.01	0.00	0.00	0.55	0.00	0.00	0.00	0.01	0.00	0.00
Eurasian Spoonbill	0.00	2.29	0.00	0.17	0.06	0.00	0.00	0.00	0.00	0.00	1.05	0.01	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00
Eurasian Wigeon	0.26	0.61	0.08	0.22	1.71	0.00	0.02	0.15	0.03	0.08	0.18	0.02	0.01	0.08	0.00	0.00	0.00	0.45	0.00	0.06
Eurasian Woodcock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
European White-fronted Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ferruginous Duck	0.00	0.00	0.00	0.08	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.06	0.03	0.00	0.00	0.03	0.00	0.03	0.05	0.00
Gadwall	0.00	1.60	0.03	3.58	0.57	0.10	0.00	0.00	0.00	2.03	0.04	0.36	0.05	0.00	0.00	0.00	0.00	0.06	0.05	0.00
Glossy Ibis	0.00	1.39	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goldeneye	0.06	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.43	0.00	0.01	0.00	0.13	0.00	0.12
Goosander	0.05	0.00	0.00	0.00	0.00	0.10	0.00	0.12	0.00	0.00	0.00	0.02	0.00	0.01	0.04	0.03	0.01	0.00	0.00	0.16
Great Black-backed Gull	0.14	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00
Great Cormorant	0.01	0.00	0.72	2.10	2.73	0.79	0.02	0.13	0.05	0.03	0.32	0.54	0.83	0.27	0.22	0.29	0.14	0.26	0.23	0.01
Great Crested Grebe	0.00	0.00	0.00	0.09	0.23	0.01	0.01	0.00	0.01	0.01	0.00	0.08	0.12	0.04	0.03	0.04	0.04	0.10	0.00	0.03
Great Northern Diver	0.00	0.00	0.00	0.05	0.02	0.00	0.05	0.00	0.18	0.00	0.00	0.00	0.04	0.03	0.00	0.00	0.00	0.06	0.00	0.00
Great Ringed Plover	0.01	0.00	0.18	0.41	0.02	0.00	0.24	0.00	0.16	0.00	0.55	0.00	0.02	0.20	0.00	0.00	0.00	0.67	0.00	0.00
Great White Egret	0.00	0.00	0.00	0.14	0.97	0.00	0.00	0.00	0.01	0.00	0.00	0.30	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Greater Flamingo	0.00	0.28	0.00	4.67	0.48	0.00	0.00	0.00	0.00	0.00	1.32	0.00	8.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Greater Scaup	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	1.36	0.00	0.00	0.00	0.00	0.00	4.84
Greater White-fronted Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Green Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grey Heron	0.00	0.02	0.01	0.73	0.23	0.00	0.00	0.00	0.01	0.00	0.13	0.11	0.10	0.01	0.02	0.03	0.01	0.02	0.00	0.01
Grey Plover	0.08	0.00	0.32	0.38	0.22	0.00	0.14	0.00	0.03	0.00	1.28	0.00	0.03	0.08	0.00	0.00	0.00	0.57	0.00	0.00
Greylag Goose	0.44	1.78	0.01	0.11	0.01	0.12	0.00	0.01	0.05	0.16	0.50	0.02	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.02
Herring Gull	2.81	0.00	0.07	0.00	0.00	0.00	0.02	0.01	0.03	0.00	0.00	0.00	0.00	0.17	0.02	0.05	0.02	0.35	0.00	0.00
Kentish Plover	0.00	0.00	0.00	0.62	0.11	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lesser Black-backed Gull	0.00	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.04	0.45	0.00
Light-bellied Brent Goose	0.00	0.00	1.08	0.00	0.00	0.00	21.66	0.00	21.79	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Little Egret	0.00	0.22	0.02	1.45	0.42	0.00	0.00	0.00	0.00	0.00	0.19	0.01	0.43	0.00	0.00	0.00	0.00	0.12	0.00	0.00
Little Grebe	0.00	0.00	0.00	0.08	0.20	0.09	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.01	0.00	0.04	0.00	0.00
Little Gull	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little Ringed Plover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little Stint	0.00	0.08	0.00	1.29	0.02	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long-tailed Duck	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02
Mallard	0.46	0.04	0.08	1.84	0.62	0.46	0.00	1.12	0.02	0.43	0.11	0.25	0.02	0.09	0.25	0.31	0.13	0.13	0.04	0.04
Marbled Teal	0.00	1.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mediterranean Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Moorhen	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Mute Swan	0.01	0.00	0.02	0.00	0.01	0.17	0.00	0.00	0.02	0.00	0.00	0.05	0.02	0.03	0.00	0.00	0.00	0.01	0.00	0.46
Northern Lapwing	0.02	0.02	0.23	0.40	0.06	0.00	0.00	0.00	0.18	0.02	0.03	0.80	0.02	0.09	0.10	0.06	0.04	0.13	0.00	0.00
Northern Pintail	2.33	1.60	3.83	3.42	0.63	0.00	0.28	0.01	0.21	5.20	0.97	0.03	0.16	0.13	0.09	0.01	0.04	2.14	0.03	0.00
Northern Shoveler	0.01	13.71	0.09	27.54	6.48	0.00	0.30	0.01	0.01	34.55	4.86	0.87	1.22	0.01	0.11	0.01	0.05	0.96	0.77	0.00
Pied Avocet	0.00	0.44	0.00	1.24	1.24	0.00	0.00	0.00	0.00	0.22	9.20	0.00	0.95	0.00	0.00	0.00	0.00	0.90	0.00	0.00
Pink-footed Goose	0.34	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.00
Purple Sandpiper	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Purple Swamphen	0.00	1.33	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Red Knot	1.90	0.00	3.37	0.00	0.02	0.00	0.56	0.00	1.23	0.00	0.14	0.00	0.00	1.32	0.00	0.00	0.00	0.07	0.00	0.00
Red-breasted Merganser	0.04	0.00	0.01	0.04	0.05	0.00	0.01	0.00	0.03	0.00	0.01	0.00	0.02	0.20	0.00	0.00	0.00	0.64	0.00	0.06
Red-crested Pochard	0.00	0.00	0.00	7.36	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Red-necked Grebe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Red-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ruddy Turnstone	0.01	0.00	0.38	0.06	0.02	0.00	0.16	0.00	0.04	0.00	0.07	0.00	0.00	0.41	0.00	0.00	0.00	0.04	0.00	0.00
Ruff	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanderling	0.26	0.00	0.23	0.36	0.04	0.00	0.15	0.00	0.00	0.00	0.05	0.00	0.01	0.10	0.00	0.00	0.00	0.00	0.00	0.00
Shag	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Slavonian Grebe	0.00	0.00	0.00	0.06	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.79	0.00	0.00	0.00	0.47	0.00	0.00
Slender-billed Gull	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smew	0.01	0.00	0.00	0.00	0.01	0.04	0.00	0.08	0.00	0.00	0.00	0.02	0.01	0.00	0.29	0.04	0.03	0.01	0.00	0.45
Spotted Redshank	0.00	0.00	0.00	0.21	0.09	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Stone Curlew	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Taiga Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Temminck's Stint	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tufted Duck	0.00	0.00	0.00	0.01	0.02	0.45	0.00	0.00	0.00	0.00	0.02	0.02	0.03	0.03	0.08	0.14	0.15	0.01	0.01	0.04
Tundra Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Velvet Scoter	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Water Rail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Western Yellow-legged Gull	0.00	0.00	0.00	0.00	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whimbrel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whiskered Tern	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White Stork	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White-headed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whooper Swan	0.14	0.00	0.03	0.01	0.00	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.19
Yellow-legged Gull	0.00	0.00	0.00	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
No. spp at 1%	**10.00**	**11.00**	**7.00**	**12.00**	**6.00**	**0.00**	**3.00**	**1.00**	**4.00**	**4.00**	**7.00**	**0.00**	**3.00**	**5.00**	**0.00**	**1.00**	**0.00**	**3.00**	**1.00**	**1.00**
WCV score	**75.44**	**35.07**	**33.13**	**80.96**	**27.72**	**3.29**	**30.40**	**1.83**	**32.63**	**44.35**	**46.43**	**5.54**	**16.77**	**20.82**	**2.79**	**3.22**	**1.89**	**32.96**	**4.81**	**7.40**

Appendix 2.1 contd

Species	Wetlands International Site Code																			
	NL00136	GB02086	GB02087	NL00168	GB02329	NL00156	NL00142	GB02369	NL00202	FR00285	ES01554	FR00299	CH00074	FR00314	CH00079	FR00319	IT00304	IT00365	ES01614	IT00445
Audouin's Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barnacle Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bar-tailed Godwit	0.04	0.36	0.28	0.01	0.91	0.00	0.00	1.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.51	0.01	0.00	0.00	0.00	0.00	0.07
Bewick's Swan	0.00	0.00	0.09	0.00	0.03	0.00	0.00	0.00	0.00	0.35	0.00	0.01	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
Black-crowned Night-heron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Black-headed Gull	0.03	0.06	0.06	0.05	0.01	0.05	0.48	0.01	0.09	0.06	0.00	0.85	0.21	0.22	0.15	0.05	0.16	0.46	0.00	0.12
Black-legged Kittiwake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-necked Grebe	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.02	0.00	0.47	0.26	0.06	0.98	0.00	0.03
Black-tailed Godwit	0.00	0.15	0.14	0.00	0.14	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-winged Stilt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caspian Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.02
Caspian Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cattle Egret	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Coot	0.21	0.00	0.00	0.15	0.02	0.13	1.07	0.00	0.46	1.19	0.00	0.29	0.53	0.12	0.75	0.22	0.79	0.70	0.00	0.65
Common Crane	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	1.40	0.00	0.00	0.00	14.73	0.00	0.00	0.00	0.00	0.00	0.00
Common Eider	0.00	0.01	0.02	0.00	0.03	0.00	0.00	0.24	0.00	0.01	0.00	0.01	0.01	0.00	0.08	0.02	0.00	0.00	0.00	0.00
Common Greenshank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Gull	0.01	0.00	0.01	0.02	0.01	0.08	0.09	0.02	0.03	0.00	0.00	0.11	0.02	0.00	0.04	0.01	0.00	0.03	0.00	0.03
Common Pochard	0.00	0.01	0.02	0.18	0.09	0.89	0.64	0.00	0.01	2.04	0.00	0.80	2.07	0.26	3.05	0.53	1.02	0.52	0.00	0.35
Common Redshank	0.03	0.73	0.50	0.00	1.05	0.00	0.00	0.85	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Scoter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Common Shelduck	0.26	0.57	0.62	0.12	0.71	0.03	0.01	0.12	0.00	0.31	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Common Snipe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Teal	0.03	0.22	0.16	0.08	0.09	0.01	0.05	0.12	0.02	2.45	0.11	0.18	0.02	0.17	0.01	0.00	0.06	0.00	0.05	0.12
Curlew Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dark-Bellied Brent Goose	0.00	1.79	1.80	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dunlin	0.58	2.72	4.19	0.19	14.67	0.04	0.00	3.19	0.00	1.32	0.00	0.00	0.00	0.02	0.00	0.00	0.08	0.00	0.00	0.51
Eurasian Bittern	0.00	0.00	0.00	0.03	0.03	0.02	0.02	0.00	0.02	0.02	0.00	0.03	0.06	0.02	0.02	0.00	0.02	0.03	0.00	0.07
Eurasian Curlew	0.08	0.30	0.13	0.10	0.45	0.30	0.06	0.31	0.02	0.02	0.00	0.01	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.03
Eurasian Golden Plover	0.23	0.36	0.25	0.19	1.61	0.01	0.00	0.01	0.04	0.02	0.08	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Eurasian Oystercatcher	0.05	0.08	0.09	0.02	0.24	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eurasian Spoonbill	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Eurasian Wigeon	0.00	0.12	0.14	0.00	0.19	0.00	0.00	0.32	0.00	0.78	0.01	0.09	0.01	0.06	0.00	0.00	0.01	0.00	0.00	0.05
Eurasian Woodcock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
European White-fronted Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ferruginous Duck	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.06	0.00	0.04	0.06	0.04	0.16	0.05	0.12	0.05	0.00	0.12
Gadwall	0.00	0.04	0.02	0.00	0.08	0.00	0.00	0.00	0.00	16.89	0.01	0.84	0.52	0.35	0.59	0.04	0.40	0.01	0.00	0.71
Glossy Ibis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Goldeneye	0.48	0.00	0.01	0.04	0.04	0.32	0.01	0.08	0.00	0.00	0.00	0.00	0.13	0.01	0.63	0.11	0.04	0.00	0.00	0.00
Goosander	0.02	0.00	0.00	0.03	0.00	2.86	0.08	0.16	0.01	0.00	0.00	0.00	0.15	0.04	0.36	0.07	0.00	0.00	0.00	0.00
Great Black-backed Gull	0.02	0.01	0.01	0.01	0.01	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Great Cormorant	0.11	0.02	0.02	0.18	0.07	1.74	0.35	0.16	0.26	1.09	0.00	0.26	0.22	0.93	0.72	0.22	1.87	0.66	0.00	0.71
Great Crested Grebe	1.34	0.00	0.00	0.03	0.00	0.21	0.05	0.00	0.01	0.26	0.00	0.06	0.65	0.16	1.88	0.87	0.16	0.44	0.00	0.03
Great Northern Diver	0.03	0.00	0.02	0.02	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.03	0.04	0.04	0.02	0.03	0.00	0.00	0.00	0.00
Great Ringed Plover	0.00	0.31	0.19	0.00	0.22	0.00	0.00	0.09	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Great White Egret	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.19	0.00	0.25	0.08	0.16	0.01	0.00	0.02	0.00	0.00	0.23
Greater Flamingo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.55	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Greater Scaup	0.01	0.00	0.02	0.01	0.03	18.06	0.00	0.06	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Greater White-fronted Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.09
Green Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grey Heron	0.01	0.00	0.00	0.01	0.00	0.01	0.04	0.01	0.06	0.05	0.00	0.03	0.04	0.03	0.03	0.01	0.02	0.01	0.00	0.03
Grey Plover	0.03	0.81	0.58	0.00	0.29	0.00	0.00	0.01	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Greylag Goose	0.00	0.01	0.01	0.00	0.05	0.00	0.00	0.29	0.00	0.27	4.40	0.02	0.02	0.48	0.00	0.00	0.00	0.00	4.55	0.01
Herring Gull	0.06	0.01	0.01	0.01	0.01	0.03	0.02	0.05	0.00	0.14	0.00	0.47	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.00
Kentish Plover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.03
Lesser Black-backed Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light-bellied Brent Goose	0.00	0.10	0.08	0.00	0.15	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little Egret	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.28	0.00	0.02	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.08
Little Grebe	0.04	0.02	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.04	0.03	0.00	0.18	0.07	0.03	0.03	0.00	0.03
Little Gull	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little Ringed Plover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little Stint	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Long-tailed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mallard	0.24	0.02	0.02	0.44	0.18	0.27	0.45	0.05	0.32	1.20	0.04	0.21	0.11	0.22	0.18	0.03	0.00	0.03	0.07	0.20
Marbled Teal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mediterranean Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00
Moorhen	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mute Swan	0.00	0.03	0.01	0.00	0.03	0.00	0.00	0.02	0.00	0.13	0.00	0.01	0.18	0.05	0.31	0.06	0.00	0.08	0.00	0.11
Northern Lapwing	0.06	0.15	0.11	0.12	0.41	0.02	0.15	0.02	0.09	0.13	0.25	0.05	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.02
Northern Pintail	0.12	0.28	0.32	0.15	0.08	0.06	0.04	0.22	0.01	3.31	0.02	0.42	0.06	0.08	0.01	0.00	0.22	0.00	0.00	0.03
Northern Shoveler	0.12	0.12	0.07	0.08	0.06	0.03	0.04	0.01	0.83	22.50	2.29	7.76	0.01	0.35	0.05	0.01	1.87	0.03	0.20	0.14
Pied Avocet	0.02	0.43	0.31	0.00	0.00	0.00	0.00	0.00	0.00	1.42	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pink-footed Goose	0.00	0.00	0.01	0.00	0.23	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple Swamphen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red Knot	0.02	0.68	0.33	0.00	4.40	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red-breasted Merganser	2.11	0.01	0.02	0.02	0.00	0.73	0.00	0.18	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.11	0.00	0.00	0.01
Red-crested Pochard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.96	0.00	0.00	4.53	0.01	1.91	0.04	0.00	0.07	0.00	0.00
Red-necked Grebe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00
Red-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ruddy Turnstone	0.03	0.27	0.17	0.00	0.25	0.00	0.00	0.14	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ruff	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanderling	0.00	0.06	0.11	0.00	0.15	0.00	0.00	0.06	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.03
Shag	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slavonian Grebe	0.97	0.06	0.04	0.00	0.04	0.00	0.00	0.13	0.00	0.06	0.00	0.03	0.05	0.04	0.06	0.07	0.00	0.06	0.00	0.03
Slender-billed Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smew	0.02	0.00	0.02	0.03	0.00	1.65	0.22	0.00	0.02	0.00	0.00	0.01	0.02	0.13	0.01	0.00	0.00	0.01	0.00	0.00
Spotted Redshank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Stone Curlew	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Taiga Bean Goose	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Temminck's Stint	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tufted Duck	0.00	0.00	0.00	0.39	0.02	1.62	0.16	0.03	0.01	0.20	0.00	0.02	1.83	0.02	2.15	0.78	0.05	0.12	0.00	0.00
Tundra Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00
Velvet Scoter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Water Rail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Western Yellow-legged Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.10	0.04	0.16	0.05	0.00	0.17
Whimbrel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whiskered Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White Stork	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White-headed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whooper Swan	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.01
Yellow-legged Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.08	0.00	0.80
No. spp at 1%	**2.00**	**2.00**	**2.00**	**0.00**	**4.00**	**5.00**	**1.00**	**2.00**	**0.00**	**13.00**	**2.00**	**1.00**	**3.00**	**1.00**	**4.00**	**0.00**	**3.00**	**0.00**	**1.00**	**0.00**
WCV score	**7.57**	**10.97**	**11.08**	**2.74**	**27.84**	**29.49**	**4.08**	**10.16**	**2.34**	**73.97**	**7.23**	**13.42**	**11.90**	**19.73**	**14.01**	**3.65**	**8.06**	**4.50**	**4.88**	**5.81**

Species	Wetlands International Site Code																		
	IT00446	IT00447	ES01970	GB02609	GB02674	FR00334	FR00341	DK00163	ES02018	GB03356	IT00494	ES02052	ES02068	ES02072	NL00157	GB03508	GB03535	NL00153	GB03644
Audouin's Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.04	0.13	0.00	0.00	0.00	0.00	0.00
Barnacle Goose	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bar-tailed Godwit	0.00	0.00	0.00	0.30	2.69	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.74	0.22	0.00	0.04	0.01	0.00	2.89
Bean Goose	0.05	0.00	0.00	0.00	0.00	0.01	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bewick's Swan	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.02	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.17	0.05	0.00	0.05
Black-crowned Night-heron	0.00	0.18	0.00	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-headed Gull	0.34	0.70	0.00	0.04	0.02	0.11	0.14	0.02	0.04	0.05	0.25	0.05	0.13	0.28	0.05	0.03	0.01	0.20	0.24
Black-legged Kittiwake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-necked Grebe	0.39	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.06	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Black-tailed Godwit	0.00	0.01	0.00	0.15	0.00	0.09	0.08	0.00	3.18	0.02	0.03	3.17	0.33	0.83	0.00	0.04	0.24	0.00	0.07
Black-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-winged Stilt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.18	1.71	0.90	0.00	0.00	0.00	0.00	0.00
Caspian Gull	0.31	0.42	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.17	0.00	0.20	0.19	0.00	0.00	0.00	0.00	0.00
Caspian Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.77	0.64	0.00	0.00	0.00	0.00	0.00
Cattle Egret	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Common Coot	1.07	1.61	0.01	0.00	0.00	0.06	0.05	0.38	0.09	0.15	0.26	0.15	0.00	0.01	0.09	0.00	0.00	0.22	0.02
Common Crane	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Eider	0.02	0.00	0.00	0.01	1.65	0.38	0.19	7.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	2.06
Common Greenshank	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.07	0.02	0.00	0.00	0.00	0.00	0.00
Common Gull	0.02	0.04	0.00	0.01	0.03	0.14	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.10
Common Pochard	0.16	0.19	0.01	0.01	0.01	0.04	0.02	0.02	0.21	4.53	0.11	0.09	0.00	0.00	2.12	0.03	0.01	0.90	0.04
Common Redshank	0.15	0.15	0.00	0.15	0.55	0.02	0.00	0.01	0.06	0.01	0.20	0.06	0.39	0.45	0.00	0.56	0.74	0.00	2.21
Common Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Scoter	0.00	0.00	0.00	0.00	0.02	0.08	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Common Shelduck	0.00	0.34	0.00	0.37	0.25	1.87	0.37	0.20	0.06	0.01	1.19	0.05	0.10	0.05	0.01	1.08	0.77	0.01	1.24
Common Snipe	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Common Teal	0.41	1.94	0.13	0.03	0.03	0.04	0.61	0.00	0.14	0.10	0.14	0.63	0.00	0.01	0.00	0.15	0.56	0.05	0.12
Curlew Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.00	0.00	0.00	0.00	0.00
Dark-Bellied Brent Goose	0.00	0.00	0.00	2.59	0.02	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.01
Dunlin	10.76	17.08	0.03	13.82	10.90	5.74	3.53	0.07	3.33	0.16	3.44	5.19	8.86	6.57	0.00	7.90	21.47	0.00	28.50
Eurasian Bittern	0.10	0.06	0.00	0.02	0.00	0.02	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.02	0.00	0.04	0.00
Eurasian Curlew	0.21	0.24	0.00	0.12	0.18	0.30	0.09	0.00	0.01	0.07	0.07	0.00	0.04	0.06	0.01	0.18	0.17	0.00	1.75
Eurasian Golden Plover	0.00	0.01	0.03	0.01	0.19	0.05	0.03	0.01	0.02	0.48	0.00	0.01	0.01	0.00	0.00	0.06	0.12	0.00	0.24
Eurasian Oystercatcher	0.00	0.00	0.00	0.12	0.08	0.64	0.04	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.00	0.15	0.01	0.00	3.92
Eurasian Spoonbill	0.00	0.30	0.02	0.00	0.00	0.10	0.05	0.00	0.43	0.00	0.58	0.00	1.99	3.47	0.00	0.00	0.00	0.00	0.00
Eurasian Wigeon	0.93	0.36	0.02	0.06	0.25	0.02	0.08	0.04	0.26	0.14	0.95	0.49	0.00	0.04	0.00	0.25	0.33	0.00	0.29
Eurasian Woodcock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
European White-fronted Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Ferruginous Duck	0.16	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.03	0.00	0.00	0.05	0.00
Gadwall	1.86	0.24	0.18	0.02	0.00	0.05	0.10	0.02	0.22	0.11	0.33	1.43	0.00	0.00	0.00	0.01	0.00	0.00	0.04
Glossy Ibis	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goldeneye	0.35	0.04	0.00	0.01	0.01	0.00	0.00	0.48	0.00	1.56	0.00	0.00	0.00	0.00	0.21	0.01	0.00	0.03	0.06
Goosander	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.04	0.01
Great Black-backed Gull	0.00	0.00	0.00	0.03	0.01	0.09	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.07
Great Cormorant	0.71	1.73	0.01	0.02	0.04	0.16	0.30	0.32	0.08	0.44	0.30	0.02	0.83	0.81	0.08	0.10	0.03	0.32	0.28
Great Crested Grebe	0.08	0.31	0.00	0.01	0.00	0.14	0.00	0.00	0.00	0.03	0.06	0.00	0.03	0.12	0.04	0.01	0.01	0.10	0.03
Great Northern Diver	0.00	0.00	0.00	0.02	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.00	0.03	0.03
Great Ringed Plover	0.00	0.01	0.00	0.32	0.15	0.09	0.08	0.00	0.27	0.00	0.00	0.00	3.00	1.45	0.00	0.32	0.04	0.00	0.36
Great White Egret	0.37	0.89	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.19	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00
Greater Flamingo	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.96	0.00	2.35	1.04	3.39	1.80	0.00	0.00	0.00	0.00	0.00
Greater Scaup	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.68	0.00	0.00	0.00	0.00	0.83	0.00	0.00	0.00	0.01
Greater White-fronted Goose	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grey Heron	0.13	0.33	0.00	0.00	0.00	0.01	0.02	0.00	0.08	0.03	0.04	0.02	0.23	0.47	0.00	0.01	0.00	0.02	0.01
Grey Plover	0.48	0.15	0.00	0.27	0.31	0.17	0.10	0.00	0.04	0.00	0.05	0.03	0.35	0.35	0.00	0.48	0.09	0.00	0.31
Greylag Goose	0.06	0.04	6.16	0.00	0.22	0.04	0.09	0.34	1.33	0.06	0.00	1.96	0.00	0.00	0.00	0.04	0.00	0.00	0.08
Herring Gull	0.00	0.00	0.00	0.01	0.01	0.59	0.18	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.08	0.70
Kentish Plover	0.04	0.13	0.00	0.00	0.00	0.01	0.00	0.00	0.61	0.00	0.49	0.03	2.14	2.31	0.00	0.00	0.00	0.00	0.00
Lesser Black-backed Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.05	0.02	0.00	0.04	0.46	1.25	0.00	0.00	0.00	0.00	0.06
Light-bellied Brent Goose	0.00	0.00	0.00	0.05	23.93	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
Little Egret	0.68	0.68	0.00	0.01	0.00	0.12	0.08	0.00	0.20	0.00	0.10	0.02	0.50	0.51	0.00	0.00	0.00	0.00	0.01
Little Grebe	0.08	0.07	0.00	0.01	0.00	0.01	0.00	0.00	0.13	0.06	0.03	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01
Little Gull	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.01
Little Ringed Plover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
Little Stint	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.29	0.00	0.22	0.18	0.76	0.32	0.00	0.00	0.00	0.00	0.00
Long-tailed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mallard	0.28	1.04	0.16	0.00	0.03	0.03	0.13	0.24	0.09	0.10	0.01	0.06	0.00	0.07	0.05	0.03	0.04	0.31	0.09
Marbled Teal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mediterranean Gull	0.08	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moorhen	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mute Swan	0.05	0.24	0.00	0.00	0.02	0.07	0.00	3.30	0.00	0.38	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.04
Northern Lapwing	0.02	0.03	0.06	0.05	0.07	0.03	0.13	0.00	0.03	0.26	0.01	0.01	0.00	0.00	0.00	0.10	0.18	0.03	0.42
Northern Pintail	0.57	7.38	0.05	0.16	0.16	1.56	0.88	0.02	0.98	0.01	1.06	5.00	0.00	0.03	0.00	0.84	5.46	0.01	1.82
Northern Shoveler	1.49	7.44	1.35	0.16	0.01	0.36	2.76	0.00	4.56	0.05	1.26	16.31	0.00	0.06	0.01	0.27	0.04	0.02	0.09
Pied Avocet	0.01	0.65	0.01	0.01	0.00	0.06	2.18	0.00	5.08	0.00	2.07	1.85	2.02	2.35	0.00	0.24	0.00	0.00	0.00
Pink-footed Goose	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.72
Purple Sandpiper	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Purple Swamphen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	5.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red Knot	0.00	0.00	0.00	0.14	0.79	0.13	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.22	0.03	0.00	8.36
Red-breasted Merganser	0.19	0.13	0.00	0.04	0.01	0.03	0.00	0.73	0.00	0.01	0.11	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.10
Red-crested Pochard	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	2.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red-necked Grebe	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red-throated Diver	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ruddy Turnstone	0.01	0.00	0.00	0.08	0.14	0.11	0.05	0.00	0.00	0.00	0.00	0.00	0.23	0.24	0.00	0.20	0.00	0.00	1.24
Ruff	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanderling	0.00	0.01	0.00	0.01	0.08	0.20	0.09	0.00	0.00	0.00	0.00	0.00	0.61	0.33	0.00	0.00	0.00	0.00	0.10
Shag	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slavonian Grebe	0.00	0.13	0.00	0.07	0.13	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.04
Slender-billed Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Smew	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	3.95	0.00	0.00	0.11	0.00
Spotted Redshank	0.01	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.07	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stone Curlew	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.03	0.00	0.00	0.00	0.00	0.00
Taiga Bean Goose	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
Temminck's Stint	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tufted Duck	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.18	0.00	1.19	0.00	0.00	0.00	0.00	2.68	0.01	0.00	0.15	0.01
Tundra Bean Goose	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Velvet Scoter	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Rail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Western Yellow-legged Gull	0.75	1.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whimbrel	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Whiskered Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White Stork	0.00	0.00	0.02	0.00	0.00	0.02	0.01	0.00	0.07	0.00	0.00	0.02	0.04	0.13	0.00	0.00	0.00	0.00	0.00
White-headed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
Whooper Swan	0.00	0.01	0.00	0.00	0.14	0.00	0.00	0.62	0.00	1.43	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.00	0.03
Yellow-legged Gull	1.18	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
No. spp at 1%	**5.00**	**8.00**	**2.00**	**2.00**	**4.00**	**3.00**	**3.00**	**2.00**	**8.00**	**4.00**	**7.00**	**10.00**	**7.00**	**7.00**	**3.00**	**2.00**	**2.00**	**0.00**	**10.00**
WCV score	**24.75**	**49.55**	**8.32**	**19.32**	**43.26**	**14.26**	**12.81**	**15.31**	**32.49**	**12.75**	**18.46**	**46.19**	**30.25**	**27.09**	**10.76**	**14.38**	**30.53**	**2.83**	**59.49**

Appendix 2.1 contd

Species	Wetlands International Site Code																			
	NL00233	NL00135	GB03790	NL00137	IT00535	IT00536	NL00222	NL00223	NL00224	NL00226	NL00227	NL00228	NL00229	NL00231	NL00230	GB03897	ES02184	FR00382	FR00394	DE02114
Audouin's Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barnacle Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bar-tailed Godwit	0.00	0.00	0.89	3.97	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.02	0.03	0.00	0.02	0.10	0.51	0.00
Bean Goose	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Bewick's Swan	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.83	0.00	0.00	0.00	0.02
Black-crowned Night-heron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Black-headed Gull	0.00	0.02	0.04	0.06	0.09	0.13	0.16	0.70	0.24	0.26	0.41	0.30	0.34	0.29	0.75	0.11	0.03	0.39	0.09	0.00
Black-legged Kittiwake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-necked Grebe	0.00	0.00	0.00	0.00	0.12	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.01	0.00
Black-tailed Godwit	0.00	0.00	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.20	2.69	0.66	0.66	0.00
Black-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-winged Stilt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.00
Caspian Gull	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Caspian Tern	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00
Cattle Egret	0.00	0.00	0.00	0.00	0.01	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.01	0.00
Common Coot	0.00	0.00	0.03	0.07	0.48	0.42	0.47	0.30	0.29	0.26	1.56	0.30	0.74	0.37	1.27	0.10	0.13	0.06	0.01	0.18
Common Crane	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.92	0.00	0.01	0.00
Common Eider	20.61	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00
Common Greenshank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Common Gull	0.00	0.50	0.03	0.06	0.00	0.00	1.30	0.61	0.64	0.17	0.34	0.47	0.46	0.15	0.50	0.02	0.00	0.03	0.00	0.00
Common Pochard	0.00	0.00	0.01	0.03	0.82	1.90	0.26	0.11	0.09	0.34	0.82	0.09	0.12	0.16	0.56	0.48	0.02	0.04	0.00	0.64
Common Redshank	0.00	0.00	0.33	0.44	0.09	0.05	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.08	0.01	0.03	0.07	0.04	0.17	0.00
Common Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Scoter	3.23	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.01	0.02	0.00
Common Shelduck	0.00	0.10	0.32	1.45	0.04	0.09	0.02	0.00	0.01	0.03	0.10	0.00	0.01	0.31	0.04	0.00	0.15	0.52	0.75	0.00
Common Snipe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00
Common Teal	0.00	0.00	0.15	0.07	0.14	0.35	0.06	0.07	0.02	0.13	0.10	0.04	0.02	0.08	0.11	0.18	2.48	0.13	0.16	0.03
Curlew Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00
Dark-Bellied Brent Goose	0.00	0.00	3.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	3.75	0.00
Dunlin	0.00	0.00	2.52	18.53	0.50	0.55	0.01	0.00	0.05	0.03	0.15	0.00	0.04	0.16	0.09	0.06	2.42	5.41	16.03	0.00
Eurasian Bittern	0.00	0.00	0.02	0.02	0.02	0.04	0.05	0.02	0.04	0.04	0.10	0.03	0.03	0.05	0.09	0.00	0.00	0.03	0.00	0.00
Eurasian Curlew	0.00	0.00	0.23	1.56	0.01	0.02	1.02	0.05	0.34	0.20	0.36	0.15	0.02	1.06	0.27	0.00	0.01	0.07	0.25	0.00
Eurasian Golden Plover	0.00	0.00	0.30	0.15	0.00	0.05	0.41	0.01	0.03	0.04	0.20	0.07	0.02	0.39	0.38	0.19	0.09	0.01	0.13	0.00
Eurasian Oystercatcher	0.00	0.00	0.29	4.35	0.00	0.00	0.03	0.00	0.01	0.00	0.16	0.00	0.00	0.30	0.09	0.00	0.03	0.16	0.18	0.00
Eurasian Spoonbill	0.00	0.00	0.00	0.01	0.73	0.04	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.05	0.01	0.00	0.70	0.49	0.03	0.00
Eurasian Wigeon	0.00	0.00	0.50	0.00	0.10	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.59	0.74	0.02	0.10	0.02
Eurasian Woodcock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
European White-fronted Goose	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ferruginous Duck	0.00	0.00	0.00	0.00	0.11	0.06	0.03	0.03	0.03	0.07	0.03	0.05	0.11	0.03	0.07	0.00	0.00	0.06	0.00	0.06
Gadwall	0.00	0.00	0.15	0.00	0.15	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	3.16	0.23	0.10	1.41
Glossy Ibis	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Goldeneye	0.00	0.01	0.03	0.43	0.00	0.00	0.01	0.00	0.01	0.02	0.04	0.00	0.01	0.05	0.04	0.00	0.00	0.00	0.00	0.05
Goosander	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.03	0.06	0.02	0.13	0.04	0.02	0.02	0.07	0.00	0.00	0.02	0.00	0.03
Great Black-backed Gull	0.00	0.47	0.01	0.04	0.00	0.00	0.00	0.00	0.01	0.00	0.05	0.00	0.00	0.05	0.06	0.00	0.00	0.02	0.01	0.00
Great Cormorant	0.00	0.00	0.06	0.05	0.80	4.01	0.13	0.21	0.19	0.25	0.40	0.32	0.15	0.14	0.56	0.10	0.22	0.33	0.05	0.29
Great Crested Grebe	0.00	0.00	0.00	0.04	0.13	0.10	0.03	0.02	0.01	0.04	0.15	0.02	0.03	0.06	0.22	0.00	0.00	0.02	0.00	0.04
Great Northern Diver	0.00	0.00	0.05	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.03	0.00	0.02	0.02	0.02	0.00	0.00	0.06	0.02	0.02
Great Ringed Plover	0.00	0.00	0.22	0.09	0.01	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.04	0.02	0.00	0.29	0.37	0.85	0.00
Great White Egret	0.00	0.00	0.00	0.00	0.33	0.52	0.08	0.05	0.05	0.05	0.04	0.09	0.08	0.01	0.08	0.00	0.00	0.05	0.00	0.00
Greater Flamingo	0.00	0.00	0.00	0.00	1.72	3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.68	0.01	0.00	0.00
Greater Scaup	0.00	0.15	0.02	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.08	0.00	0.00	0.01	0.39	0.00	0.00	0.01	0.00	0.00
Greater White-fronted Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grey Heron	0.00	0.00	0.01	0.01	0.14	0.15	0.09	0.09	0.10	0.05	0.15	0.10	0.09	0.11	0.18	0.01	0.02	0.06	0.01	0.01
Grey Plover	0.00	0.00	0.34	1.89	0.01	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.01	0.00	0.04	0.14	0.86	0.00
Greylag Goose	0.00	0.00	0.13	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	9.37	0.01	0.09	0.00
Herring Gull	0.00	1.59	0.11	0.34	0.00	0.02	0.05	0.04	0.18	0.06	0.46	0.02	0.03	0.60	0.65	0.00	0.00	0.93	0.05	0.00
Kentish Plover	0.00	0.00	0.00	0.00	0.02	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.01	0.00	0.00
Lesser Black-backed Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	1.40	0.02	0.02	0.00
Light-bellied Brent Goose	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.00
Little Egret	0.00	0.00	0.04	0.01	0.17	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01	0.00	0.05	1.15	0.01	0.00
Little Grebe	0.00	0.00	0.01	0.04	0.08	0.06	0.00	0.03	0.00	0.02	0.06	0.02	0.01	0.11	0.03	0.00	0.01	0.01	0.00	0.03
Little Gull	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.06	0.06	0.00	0.00
Little Ringed Plover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Little Stint	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.57	0.01	0.01	0.00
Long-tailed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mallard	0.00	0.00	0.06	0.42	0.08	0.11	0.93	0.41	0.99	0.69	1.32	0.56	0.49	0.82	0.92	0.15	0.07	0.07	0.11	0.34
Marbled Teal	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Mediterranean Gull	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moorhen	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.03	0.01	0.03	0.10	0.02	0.04	0.12	0.08	0.01	0.00	0.01	0.00	0.00
Mute Swan	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.02	0.02	0.04
Northern Lapwing	0.00	0.00	0.23	0.10	0.06	0.14	0.22	0.11	0.05	0.09	0.22	0.06	0.12	0.34	0.21	0.22	0.14	0.26	0.11	0.00
Northern Pintail	0.00	0.00	0.82	2.42	0.36	0.53	0.04	0.03	0.05	0.23	0.03	0.03	0.01	0.36	0.09	1.67	1.90	0.29	0.43	0.01
Northern Shoveler	0.00	0.00	0.22	2.04	1.61	5.27	0.19	0.10	0.17	0.47	0.67	0.07	0.07	0.77	0.93	0.49	37.65	1.61	1.10	0.07
Pied Avocet	0.00	0.00	0.03	0.34	0.32	0.25	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.10	0.02	0.00	0.66	1.59	0.72	0.00
Pink-footed Goose	0.00	0.00	4.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.12	0.05	0.00	0.00	0.06	0.01	0.00
Purple Swamphen	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00
Red Knot	0.00	0.00	1.06	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.01	0.01	0.00	0.00	0.01	1.81	0.00
Red-breasted Merganser	0.00	0.01	0.03	0.29	0.04	0.00	0.01	0.00	0.01	0.01	0.05	0.00	0.00	0.10	0.03	0.00	0.00	0.01	0.00	0.00
Red-crested Pochard	0.00	0.00	0.01	0.00	0.01	0.06	0.01	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.01	0.00	0.70	0.00	0.00	0.01
Red-necked Grebe	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ruddy Turnstone	0.00	0.25	0.29	0.77	0.00	0.05	0.01	0.00	0.00	0.00	0.36	0.00	0.00	0.49	0.11	0.00	0.00	0.80	0.16	0.00
Ruff	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00
Sanderling	0.00	2.18	0.28	0.13	0.01	0.01	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.23	0.43	0.00	0.15	0.07	0.28	0.00
Shag	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Slavonian Grebe	0.00	0.00	0.11	0.40	0.09	0.00	0.07	0.03	0.03	0.06	0.08	0.00	0.05	0.06	0.08	0.00	0.00	0.08	0.00	0.04
Slender-billed Gull	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smew	0.00	0.00	0.01	0.03	0.00	0.00	0.26	0.10	0.08	0.08	0.31	0.15	0.09	0.10	0.20	0.00	0.00	0.01	0.00	0.02
Spotted Redshank	0.00	0.00	0.01	0.04	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.20	0.02	0.02	0.00
Stone Curlew	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Taiga Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Temminck's Stint	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tufted Duck	0.00	0.00	0.00	0.02	0.03	0.04	0.25	0.09	0.15	0.15	0.93	0.06	0.13	0.22	0.54	0.04	0.00	0.01	0.00	0.49
Tundra Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Velvet Scoter	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Rail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Western Yellow-legged Gull	0.00	0.00	0.00	0.00	0.13	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whimbrel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whiskered Tern	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
White Stork	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.05	0.00	0.20	0.01	0.00	0.00
White-headed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00
Whooper Swan	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.00	0.00	0.00	0.00
Yellow-legged Gull	0.00	0.00	0.00	0.00	0.24	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
No. spp at 1%	**2.00**	**2.00**	**4.00**	**9.00**	**2.00**	**4.00**	**2.00**	**0.00**	**0.00**	**0.00**	**2.00**	**0.00**	**0.00**	**1.00**	**1.00**	**4.00**	**10.00**	**4.00**	**4.00**	**1.00**
WCV score	**23.84**	**5.36**	**18.45**	**44.84**	**9.90**	**21.75**	**6.35**	**3.36**	**3.96**	**3.96**	**10.62**	**3.08**	**3.47**	**8.81**	**10.39**	**21.34**	**73.16**	**18.01**	**29.76**	**3.86**

Appendix 2.1 contd

Species	Wetlands International Site Code																			
	GB04224	DK00221	FR00463	GB04908	IE00490	GB05017	GB05021	GB05042	IT00640	GB05193	GB05205	GB05261	DK00264	GB05353	GB05382	IT00670	IT00671	IT00696	ES02035	CH00135
Audouin's Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barnacle Goose	0.00	0.00	0.00	0.01	0.00	3.08	0.00	0.00	0.00	0.00	0.04	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bar-tailed Godwit	3.82	0.00	0.01	0.01	0.16	1.92	0.00	0.00	0.00	0.07	0.60	0.34	0.00	3.29	6.81	0.00	0.00	0.00	0.05	0.00
Bean Goose	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Bewick's Swan	0.66	0.01	0.00	1.32	0.00	0.11	0.61	0.00	0.03	0.02	0.03	0.10	0.00	0.09	0.18	0.00	0.00	0.00	0.00	0.00
Black-crowned Night-heron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00
Black-headed Gull	0.09	0.07	0.01	0.20	0.05	0.06	0.09	0.00	0.09	0.12	0.12	0.03	0.00	0.62	0.17	1.17	0.00	0.07	0.11	0.18
Black-legged Kittiwake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-necked Grebe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.37	0.25	0.02
Black-tailed Godwit	0.50	0.00	0.00	0.04	0.40	0.01	0.02	0.00	0.02	0.54	0.07	0.31	0.00	0.40	0.43	0.00	0.00	0.00	5.16	0.00
Black-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-winged Stilt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.72	0.00
Caspian Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.03	0.00
Caspian Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00
Cattle Egret	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
Common Coot	0.01	0.72	0.01	0.04	0.00	0.00	0.01	0.00	0.21	0.00	0.02	0.03	0.53	0.05	0.01	0.00	1.66	0.79	0.13	0.28
Common Crane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00
Common Eider	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.02	19.53	0.01	0.43	0.00	0.00	0.00	0.00	0.03
Common Greenshank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Common Gull	0.08	0.02	0.00	0.04	0.01	0.06	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.07	0.06	0.00	0.00	0.00	0.00	0.02
Common Pochard	0.01	0.06	0.00	0.26	0.00	0.00	0.04	0.00	0.06	0.02	0.03	0.03	0.07	0.15	0.02	0.00	0.54	0.26	0.37	0.41
Common Redshank	0.44	0.01	0.02	0.61	0.21	0.64	0.01	0.00	0.25	0.62	0.75	0.37	0.00	1.03	0.83	0.00	0.00	0.04	0.17	0.00
Common Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Scoter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Common Shelduck	0.78	0.05	0.46	0.51	0.18	0.23	0.01	0.00	0.10	0.64	0.88	0.62	0.15	0.85	3.64	0.00	0.00	0.12	0.08	0.00
Common Snipe	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Common Teal	0.23	0.02	0.03	0.20	0.08	0.04	0.66	0.00	0.10	0.04	0.13	0.17	0.01	0.24	0.06	0.00	0.04	0.11	0.39	0.00
Curlew Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dark-Bellied Brent Goose	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.42	0.00	0.66	0.11	2.74	6.72	0.00	0.00	0.00	0.00	0.00
Dunlin	13.58	0.46	3.78	22.97	3.69	7.57	0.28	0.00	2.16	8.49	2.75	6.16	0.15	19.52	21.67	0.01	0.05	0.28	9.07	0.00
Eurasian Bittern	0.00	0.00	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.00	0.00
Eurasian Curlew	0.15	0.02	0.04	0.65	0.40	0.63	0.00	0.00	0.03	0.19	0.34	0.24	0.02	0.53	0.56	0.00	0.00	0.02	0.02	0.00
Eurasian Golden Plover	0.26	0.00	0.06	0.09	0.47	0.42	0.54	0.00	0.00	0.03	0.44	0.43	0.00	0.24	0.64	0.00	0.00	0.02	0.09	0.00
Eurasian Oystercatcher	0.92	0.00	0.00	0.03	0.02	2.41	0.00	0.00	0.00	0.11	0.57	0.39	0.01	1.50	1.28	0.00	0.00	0.00	0.00	0.00
Eurasian Spoonbill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.07	2.23	0.00
Eurasian Wigeon	1.78	0.06	0.08	0.37	0.21	0.10	0.69	0.00	0.12	0.17	0.09	0.65	0.09	0.25	0.16	0.00	0.20	0.14	0.16	0.00
Eurasian Woodcock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
European White-fronted Goose	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Ferruginous Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.07	0.00	0.06
Gadwall	0.01	0.02	1.33	0.35	0.00	0.01	0.43	0.00	0.10	0.03	0.11	0.10	0.00	0.31	0.10	0.00	1.01	0.20	0.86	0.05
Glossy Ibis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00
Goldeneye	0.00	0.90	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.05	0.00	0.72	0.00	0.03	0.00	0.00	0.10	0.00	0.05
Goosander	0.00	0.61	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Great Black-backed Gull	0.01	0.02	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.14	0.04	0.00	0.00	0.00	0.00	0.00
Great Cormorant	0.15	0.09	0.24	0.06	0.09	0.23	0.07	0.00	0.80	0.05	0.09	0.06	0.59	0.22	0.14	0.02	1.26	0.80	0.44	0.08
Great Crested Grebe	0.00	0.03	0.01	0.00	0.00	0.01	0.00	0.00	0.04	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.21	0.18	0.00	0.22
Great Northern Diver	0.00	0.00	0.00	0.00	0.04	0.02	0.02	0.00	0.00	0.04	0.05	0.02	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.02
Great Ringed Plover	0.04	0.00	0.01	0.21	0.00	0.47	0.00	0.00	0.08	0.22	0.17	0.20	0.00	0.68	0.13	0.00	0.00	0.00	0.19	0.00
Great White Egret	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.64	0.01	0.01
Greater Flamingo	0.00	0.00	11.84	0.00	0.00	0.00	0.00	0.00	4.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	8.10	0.00
Greater Scaup	0.01	0.01	0.00	0.00	0.03	0.14	0.00	0.00	0.00	0.00	0.01	0.00	0.92	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Greater White-fronted Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Green Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Grey Heron	0.00	0.02	0.01	0.01	0.00	0.01	0.04	0.00	0.08	0.00	0.02	0.01	0.00	0.03	0.01	0.00	0.02	0.23	0.13	0.02
Grey Plover	0.52	0.00	0.07	0.15	0.01	0.17	0.01	0.00	0.09	0.53	0.03	0.42	0.00	1.12	1.55	0.00	0.00	0.00	0.17	0.00
Greylag Goose	0.01	0.18	0.00	0.05	0.01	0.06	0.01	0.00	0.00	0.01	0.07	0.08	0.26	0.04	0.05	0.00	0.00	0.12	0.46	0.00
Herring Gull	0.39	0.11	0.00	0.07	0.01	0.05	0.00	0.00	0.00	0.01	0.04	0.02	0.00	0.19	0.35	0.00	0.00	0.00	0.00	0.00
Kentish Plover	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	1.38	0.00
Lesser Black-backed Gull	0.01	0.00	0.00	0.21	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.08	0.03	0.00	0.00	0.00	0.39	0.00
Light-bellied Brent Goose	0.02	0.00	0.00	0.03	0.20	0.02	0.02	0.00	0.00	0.00	56.06	0.04	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00
Little Egret	0.01	0.00	0.01	0.01	0.00	0.00	0.02	0.00	0.25	0.01	0.01	0.01	0.00	0.03	0.03	0.00	0.02	0.12	0.62	0.00
Little Grebe	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.03	0.03	0.00	0.04	0.01	0.00	0.10	0.12	0.07	0.04
Little Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01
Little Ringed Plover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
Little Stint	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	1.10	0.00
Long-tailed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mallard	0.05	0.16	0.06	0.13	0.01	0.05	0.04	0.00	0.04	0.04	0.05	0.06	0.18	0.06	0.12	0.00	0.06	0.21	0.20	0.08
Marbled Teal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.00
Mediterranean Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moorhen	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
Mute Swan	0.02	1.60	0.03	0.06	0.01	0.01	0.17	0.00	0.00	0.10	0.03	0.04	1.32	0.06	0.01	0.00	0.00	0.00	0.00	0.06
Northern Lapwing	0.40	0.00	0.00	0.32	0.74	0.25	1.75	0.00	0.06	0.07	0.31	0.34	0.00	0.36	0.36	0.00	0.01	0.06	0.09	0.00
Northern Pintail	1.53	0.01	0.02	0.73	0.01	1.26	0.43	0.00	0.54	0.57	0.36	0.59	0.04	0.27	1.58	0.00	0.01	0.05	4.46	0.00
Northern Shoveler	0.20	0.03	1.07	0.49	0.01	0.06	1.09	0.00	0.98	0.03	0.27	0.56	0.02	0.49	0.03	0.00	0.20	0.82	20.75	0.02
Pied Avocet	0.00	0.00	1.04	0.01	0.00	0.00	0.00	0.00	0.57	0.10	0.00	0.17	0.00	0.53	0.00	0.00	0.00	0.24	7.05	0.00
Pink-footed Goose	1.33	0.00	0.00	0.00	0.00	0.95	0.00	7.83	0.00	0.00	0.00	0.00	0.00	0.00	4.08	0.00	0.00	0.00	0.00	0.00
Purple Sandpiper	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Purple Swamphen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.22	0.00
Red Knot	2.78	0.00	0.01	0.30	0.02	1.63	0.00	0.00	0.00	0.45	1.45	0.54	0.00	4.52	12.60	0.00	0.00	0.00	0.00	0.00
Red-breasted Merganser	0.00	0.02	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.07	0.01	0.56	0.01	0.02	0.01	0.00	0.01	0.00	0.00
Red-crested Pochard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.57	6.71
Red-necked Grebe	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ruddy Turnstone	0.13	0.00	0.00	0.22	0.04	0.32	0.00	0.00	0.03	0.30	0.22	0.22	0.00	0.37	0.51	0.00	0.00	0.00	0.00	0.00
Ruff	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Sanderling	1.08	0.00	0.05	0.02	0.01	0.10	0.00	0.00	0.02	0.02	0.08	0.02	0.00	0.14	0.21	0.00	0.00	0.09	0.00	0.00
Shag	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slavonian Grebe	0.00	0.04	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.04	0.00	0.03	0.00	0.09	0.04	0.00	0.00	0.03	0.00	0.03
Slender-billed Gull	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Smew	0.00	0.26	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.00	0.01	0.01	0.00	0.00
Spotted Redshank	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.09	0.00
Stone Curlew	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Taiga Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Temminck's Stint	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tufted Duck	0.01	1.28	0.00	0.04	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.59	0.04	0.01	0.00	0.01	0.01	0.00	0.43
Tundra Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Velvet Scoter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Rail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Western Yellow-legged Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.02	1.02	0.04	0.01
Whimbrel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whiskered Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.38	0.00
White Stork	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00
White-headed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	4.49	0.00
Whooper Swan	0.10	0.71	0.00	0.00	0.34	0.13	0.01	0.00	0.00	0.00	0.11	0.00	0.80	0.01	0.02	0.00	0.00	0.00	0.00	0.00
Yellow-legged Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.56	0.00	0.00
No. spp at 1%	**7.00**	**2.00**	**5.00**	**2.00**	**1.00**	**6.00**	**2.00**	**1.00**	**2.00**	**1.00**	**3.00**	**1.00**	**2.00**	**7.00**	**9.00**	**1.00**	**3.00**	**1.00**	**13.00**	**1.00**
WCV score	**32.15**	**8.26**	**20.81**	**31.20**	**7.52**	**23.39**	**7.20**	**7.83**	**14.62**	**14.16**	**66.83**	**14.26**	**26.86**	**41.56**	**65.85**	**1.66**	**6.31**	**8.86**	**79.31**	**8.87**

Species	NL00169	NL00140	NL00149	NL00134	NL00232	DE02799	DE02800	DE02801	DE02802	DE02803	DE02804	DE02805	DE02806	NL00139	IE00555	BE01026	NL00014	CH00146
	Wetlands International Site Code																	
Audouin's Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barnacle Goose	0.00	0.00	0.00	0.00	0.00	0.24	0.01	0.59	0.01	0.96	0.61	0.58	1.26	0.00	0.00	0.06	6.20	0.00
Bar-tailed Godwit	0.11	0.17	0.00	21.29	0.00	1.35	1.76	0.64	0.07	0.00	0.11	0.01	0.14	0.79	0.62	0.00	0.00	0.00
Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.04	0.04	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.01
Bewick's Swan	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.06	0.00	0.01	0.09	0.04	0.01	0.00	0.66	0.00	0.00	0.00
Black-crowned Night-heron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-headed Gull	0.02	0.05	0.20	0.36	0.00	0.01	0.01	0.01	0.00	0.01	0.02	0.01	0.01	0.12	0.05	0.00	0.00	0.35
Black-legged Kittiwake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-necked Grebe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Black-tailed Godwit	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.42	0.00	0.00	0.00
Black-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-winged Stilt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caspian Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caspian Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cattle Egret	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Coot	0.09	0.01	0.32	0.14	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.47
Common Crane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Eider	0.00	0.00	0.00	0.00	124.36	6.46	5.11	3.10	2.58	2.68	0.67	0.62	0.07	0.00	0.00	0.00	0.00	0.02
Common Greenshank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Gull	0.01	0.08	0.03	1.28	0.00	0.05	0.07	0.03	0.01	0.10	0.06	0.03	0.03	0.04	0.01	0.00	0.00	0.02
Common Pochard	0.14	0.10	0.73	0.06	0.00	0.02	0.00	0.04	0.00	0.00	0.01	0.01	0.00	0.01	0.02	0.00	0.00	0.44
Common Redshank	0.01	0.10	0.00	3.20	0.00	0.09	0.14	0.12	0.04	0.08	0.06	0.04	0.02	0.21	0.07	0.00	0.00	0.00
Common Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Scoter	0.00	0.00	0.00	0.00	0.04	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Shelduck	0.18	0.06	0.00	10.28	0.00	1.91	1.87	2.84	0.83	3.99	0.36	0.58	0.18	0.44	0.13	0.00	0.00	0.00
Common Snipe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Teal	0.04	0.04	0.02	0.29	0.00	0.04	0.01	0.05	0.00	0.00	0.00	0.02	0.01	0.12	0.08	0.00	0.00	0.01
Curlew Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dark-Bellied Brent Goose	0.00	0.00	0.00	0.00	0.00	0.13	0.16	0.18	0.06	0.04	0.01	0.01	0.01	0.00	0.54	0.01	0.00	0.00
Dunlin	0.59	1.78	0.00	80.41	0.00	3.00	3.28	5.63	1.43	2.43	0.47	1.12	2.83	19.52	1.53	0.00	0.00	0.00
Eurasian Bittern	0.02	0.00	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.02
Eurasian Curlew	0.07	0.19	0.05	19.90	0.00	0.35	0.55	1.09	0.47	0.94	0.54	0.71	0.72	0.61	0.14	0.00	0.00	0.03
Eurasian Golden Plover	0.03	0.03	0.01	0.76	0.00	0.03	0.08	0.03	0.02	0.01	0.00	0.01	0.01	0.26	0.57	0.00	0.00	0.00
Eurasian Oystercatcher	0.13	0.28	0.00	19.56	0.00	0.60	1.28	1.49	1.24	1.13	0.48	0.32	0.41	1.11	0.03	0.00	0.00	0.00
Eurasian Spoonbill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eurasian Wigeon	0.00	0.00	0.00	0.00	0.00	0.35	0.38	0.60	0.37	0.65	0.21	0.31	0.14	0.00	0.19	0.00	0.00	0.00
Eurasian Woodcock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
European White-fronted Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ferruginous Duck	0.07	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Gadwall	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.08	0.00	0.00	0.03	0.01	0.00	0.00	0.03	0.00	0.00	0.23
Glossy Ibis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goldeneye	0.32	0.17	0.00	0.13	0.00	0.03	0.00	0.11	0.00	0.02	0.02	0.04	0.00	0.00	0.02	0.00	0.00	0.05
Goosander	0.01	0.00	0.02	0.23	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.07
Great Black-backed Gull	0.01	0.11	0.00	0.55	0.00	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.04	0.01	0.00	0.00	0.00
Great Cormorant	0.36	0.29	0.17	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.09	0.00	0.00	0.37
Great Crested Grebe	0.08	0.04	0.03	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.02	0.00	0.00	0.39
Great Northern Diver	0.02	0.03	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.33	0.00	0.00	0.03
Great Ringed Plover	0.00	0.05	0.00	0.12	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.10	0.10	0.00	0.00	0.00
Great White Egret	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
Greater Flamingo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Greater Scaup	0.00	0.52	0.00	7.24	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.07	0.00	0.00	0.00
Greater White-fronted Goose	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.02	0.05	0.00	0.00	0.82	2.06	2.24	0.00
Green Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grey Heron	0.01	0.01	0.02	0.05	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.02
Grey Plover	0.02	0.09	0.00	4.18	0.00	0.05	0.17	0.52	0.11	0.09	0.08	0.16	0.09	0.62	0.15	0.00	0.00	0.00
Greylag Goose	0.00	0.00	0.00	0.00	0.00	0.11	0.06	0.06	0.01	0.02	0.17	0.07	0.13	0.00	0.00	1.18	0.07	0.00
Herring Gull	0.02	0.65	0.01	3.32	0.00	0.22	0.10	0.21	0.05	0.12	0.11	0.06	0.08	0.74	0.00	0.00	0.00	0.00
Kentish Plover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lesser Black-backed Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light-bellied Brent Goose	0.00	0.00	0.00	0.00	0.00	0.18	0.04	0.00	0.00	0.04	0.00	0.10	0.02	0.00	48.68	0.47	0.00	0.00
Little Egret	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Little Grebe	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.06
Little Gull	0.00	0.01	0.00	0.04	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Little Ringed Plover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little Stint	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long-tailed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mallard	0.42	0.03	0.19	1.83	0.00	0.14	0.11	0.23	0.07	0.28	0.24	0.25	0.21	0.75	0.03	0.00	0.00	0.14
Marbled Teal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mediterranean Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moorhen	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mute Swan	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.05	0.00	0.12	0.11
Northern Lapwing	0.03	0.01	0.10	0.15	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.35	0.00	0.00	0.00
Northern Pintail	0.32	0.81	0.07	11.25	0.00	0.52	0.14	0.23	0.00	0.15	0.10	0.33	0.24	4.72	0.10	0.00	0.00	0.00
Northern Shoveler	0.13	0.06	0.08	1.30	0.00	0.32	0.09	0.26	0.00	0.05	0.09	0.06	0.01	0.11	0.04	0.00	0.00	0.03
Pied Avocet	0.03	0.08	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00
Pink-footed Goose	0.00	0.00	0.00	0.00	0.00	0.05	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.08	0.00
Purple Sandpiper	0.00	0.01	0.00	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple Swamphen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red Knot	0.03	0.02	0.00	11.26	0.00	0.27	0.70	0.87	0.16	0.11	0.04	0.01	0.01	0.32	0.05	0.00	0.00	0.00
Red-breasted Merganser	0.06	0.10	0.00	0.51	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.07	0.08	0.00	0.00	0.00
Red-crested Pochard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15
Red-necked Grebe	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Red-throated Diver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ruddy Turnstone	0.01	0.08	0.00	2.39	0.00	0.03	0.03	0.12	0.08	0.01	0.01	0.01	0.00	0.31	0.03	0.00	0.00	0.00
Ruff	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanderling	0.00	0.23	0.00	1.46	0.00	0.04	0.06	0.00	0.03	0.04	0.08	0.00	0.01	0.46	0.09	0.00	0.00	0.00
Shag	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slavonian Grebe	0.06	0.15	0.00	0.05	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.11	0.00	0.00	0.03
Slender-billed Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smew	0.01	0.03	0.22	0.19	0.00	0.02	0.01	0.14	0.00	0.01	0.06	0.05	0.01	0.00	0.00	0.00	0.00	0.01
Spotted Redshank	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Stone Curlew	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Taiga Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00
Temminck's Stint	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tufted Duck	0.33	0.01	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.41
Tundra Bean Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00
Velvet Scoter	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Rail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Western Yellow-legged Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Whimbrel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whiskered Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White Stork	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White-headed Duck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whooper Swan	0.00	0.00	0.00	0.00	0.00	0.12	0.03	0.09	0.04	0.02	0.02	0.19	0.00	0.00	0.14	0.00	0.01	0.00
Yellow-legged Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
No. species at 1% level	**0.00**	**1.00**	**0.00**	**16.00**	**1.00**	**4.00**	**5.00**	**5.00**	**3.00**	**4.00**	**0.00**	**1.00**	**2.00**	**3.00**	**2.00**	**3.00**	**2.00**	**0.00**
Total WCV score	**3.81**	**6.54**	**2.43**	**205.47**	**124.39**	**16.92**	**16.48**	**19.62**	**7.82**	**14.09**	**4.83**	**5.88**	**6.68**	**32.58**	**56.54**	**7.99**	**8.71**	**3.61**

Appendix 2.2 Matrix of mean Waterbird Conservation Value (WCV) scores for 22 sites and 99 waterbird species in western Africa during January. Data on which the scores are based were sourced from International Waterbird Census database, Wetlands International (T. Langedoen in litt.).

Species	Wetlands International Site Code																					
	MA00022	CM00007	NG00001	MR00005	GH00003	MR00012	MR00015	CM00023	CM00026	NG00011	BF00006	MR00019	NE00033	NE00035	NE00038	MA00147	MA00148	SN00019	SN00025	SN00026	GN00010	CM00055
African Darter	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.8	0.0	0.0
African Openbill Stork	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
African Purple Swamphen	0.0	0.0	0.0	0.0	0.0	2.2	0.1	0.0	0.0	0.0	13.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
African Pygmy Goose	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.1
African Sacred Ibis	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
African Skimmer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0
African Spoonbill	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Audouin's Gull	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.7	0.0	0.0
Bar-tailed Godwit	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.4	0.0
Black Heron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Black Stork	0.0	0.0	0.0	1.2	0.0	0.0	1.1	0.0	0.0	0.0	0.0	5.5	0.0	0.0	0.0	0.0	0.0	0.4	0.3	0.0	0.0	0.0
Black Tern	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Black-crowned Crane	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.7	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.8
Black-crowned Night-heron	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	0.0	0.0	0.0
Black-headed Gull	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Black-headed Heron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Black-tailed Godwit	0.1	7.8	0.0	0.1	0.4	0.0	0.0	0.0	0.0	2.7	6.9	0.3	0.0	0.0	0.0	4.5	4.1	1.4	0.8	0.4	0.0	0.8
Black-winged Stilt	0.0	0.2	0.3	0.2	2.6	0.3	0.2	0.1	0.0	0.5	4.4	6.6	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.8	1.6	0.1
Caspian Tern	12.3	0.0	0.0	2.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.1	0.1	0.1	0.6	26.1	1.4	0.0
Cattle Egret	0.0	0.1	0.5	0.0	0.0	0.3	0.6	0.1	2.8	0.9	1.2	0.4	0.0	0.1	0.0	0.1	0.0	0.0	0.0	1.4	0.0	2.3
Comb Duck	0.0	0.5	1.2	0.0	0.0	0.2	0.3	0.1	0.8	0.1	2.7	0.4	0.0	0.0	0.0	0.0	0.0	0.3	2.7	0.0	0.0	0.1
Common Coot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.9	0.0	0.0	0.0	0.0	0.0
Common Greenshank	0.0	0.0	0.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Common Moorhen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common Pochard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common Pratincole	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.0	5.3	0.0	1.7	17.3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0
Common Redshank	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.1	0.0	0.0	1.6	0.2	0.0
Common Ringed Plover	1.4	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.0	0.0	0.0	5.0	4.7	0.0	0.0	4.1	0.9	0.0
Common Sandpiper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common Shelduck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	2.1	0.0	0.0	0.0	0.0	0.0
Common Snipe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common Teal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	0.0	0.0
Common Tern	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Common Whimbrel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.0
Curlew Sandpiper	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	2.2	1.3	0.0
Dunlin	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	1.3	0.0	0.0	0.1	0.0	0.0
Egyptian Goose	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.9	0.0	0.0	0.0
Eurasian Curlew	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Eurasian Golden Plover	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0
Eurasian Oystercatcher	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Eurasian Spoonbill	0.3	0.0	0.0	4.5	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	3.8	3.9	0.0	0.0
Eurasian Wigeon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2	4.6	0.0	0.0	0.0	0.0	0.0
Fulvous Duck	0.0	0.2	0.1	0.1	0.9	0.0	0.0	0.0	0.0	0.1	3.9	1.1	75.1	29.3	0.0	0.0	0.0	0.1	1.9	0.0	0.0	0.0
Gadwall	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0
Garganey	0.0	4.3	1.2	0.1	0.0	0.3	0.7	0.9	11.7	8.3	1.1	1.8	0.0	0.0	0.0	0.0	0.0	0.1	4.4	0.0	0.0	0.1
Glossy Ibis	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Great Snipe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Great White Egret	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3
Great White Pelican	0.0	0.0	0.0	10.8	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	19.4	0.1	0.2	0.1
Greater Flamingo	2.1	0.0	0.0	16.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.8	0.7	21.2	4.4	0.7	0.0
Green Sandpiper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Green-backed Heron	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grey Heron	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Grey Plover	0.8	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.8	0.0	0.0	1.6	0.2	0.0
Grey-headed Gull	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	1.1	0.3
Greylag Goose	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.5	0.0	0.0	0.0	0.0	0.0
Gull-billed Tern	0.0	0.0	0.0	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.6	0.0
Intermediate Egret	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kentish Plover	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	12.4	0.4	0.0	3.5	0.0	0.0
Kittlitz's Plover	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.6	0.5	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.5	0.0	0.0
Lesser Black-backed Gull	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.9	0.0	0.0
Lesser Flamingo	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.5	0.0	45.0	0.0
Little Egret	0.0	0.0	0.3	0.2	1.8	0.0	0.1	0.0	0.0	0.8	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	1.6	0.1	0.3
Little Grebe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0
Little Ringed Plover	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Little Stint	0.2	0.0	0.0	0.1	2.1	0.1	0.0	0.0	0.0	0.0	0.3	1.1	0.0	0.0	0.0	6.9	4.9	0.4	0.0	6.7	1.1	0.0
Little Tern	0.0	0.0	0.0	0.1	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.2	0.0
Mallard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Marsh Sandpiper	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0
Northern Lapwing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Northern Pintail	0.0	2.5	0.0	0.0	0.0	0.3	0.2	0.1	3.6	0.0	0.0	1.4	0.0	0.0	0.0	0.2	0.1	0.4	10.2	0.0	0.1	0.0
Northern Shoveler	0.0	0.4	0.0	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	1.5	0.7	0.1	1.7	0.0	0.0	0.0
Pied Avocet	0.0	0.0	0.0	0.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	5.4	0.2	0.1	3.3	0.8	0.0
Pink-backed Pelican	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.1	0.0
Purple Heron	0.0	0.1	0.7	0.1	0.1	0.0	0.1	0.0	0.2	0.4	0.5	0.1	0.1	0.0	0.0	0.0	0.0	0.0	1.2	0.1	0.0	0.1
Red Knot	1.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Red-knobbed Coot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.8	0.0	0.0	0.0	0.0	0.0
Reed Cormorant	0.0	1.3	0.8	0.2	0.4	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	1.9	0.0	0.1
Royal Tern	0.1	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.8	0.0
Ruddy Turnstone	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	2.9	0.1	0.0
Ruff	0.0	0.2	0.2	0.0	0.0	0.0	1.1	0.1	0.4	1.4	0.2	0.2	0.0	15.3	0.0	0.0	0.0	1.1	0.8	0.1	0.0	0.5
Sanderling	2.1	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	1.0	0.2	0.0
Sandwich Tern	0.2	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.2	0.0
Senegal Thick-knee	0.0	0.0	0.2	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.1	0.0	0.0
Slender-billed Gull	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	33.1	0.0	0.0
Spotted Redshank	0.0	0.0	0.0	0.1	3.3	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Spur-winged Goose	0.0	0.0	0.1	0.0	0.0	0.2	0.2	0.0	2.5	0.1	6.5	1.7	0.0	0.0	0.0	0.0	0.0	0.2	0.8	0.0	0.0	1.3
Spur-winged Plover	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Squacco Heron	0.0	2.3	7.5	0.2	3.6	0.1	0.8	0.4	10.0	129.5	2.6	0.1	11.4	0.4	0.0	0.0	0.0	0.4	2.3	0.0	0.0	185.2
Temminck's Stint	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tufted Duck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Western Reef Egret	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0
Whiskered Tern	0.0	0.0	0.0	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0
White Stork	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
White-breasted Cormorant	1.6	0.0	0.0	1.4	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	6.9	2.0	0.0	0.0
White-faced Duck	0.0	3.7	3.9	0.1	3.0	2.7	0.1	0.5	0.4	0.4	4.9	3.6	65.8	18.0	5.3	0.0	0.0	0.1	14.6	0.0	1.2	0.6
White-fronted Plover	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.4	0.0
Wood Sandpiper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow-billed Stork	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.1
No. species at 1% level	**10**	**6**	**4**	**7**	**10**	**2**	**2**	**0**	**6**	**5**	**12**	**12**	**3**	**3**	**1**	**13**	**10**	**3**	**15**	**26**	**11**	**5**
Total WCV score	**34.6**	**24.4**	**17.7**	**48.1**	**33.6**	**7.1**	**6.9**	**2.5**	**39.5**	**149.8**	**54.3**	**50.0**	**152.6**	**63.1**	**5.3**	**55.1**	**47.9**	**11.5**	**110.5**	**131.6**	**65.0**	**195.8**

Appendix 2.3 Matrix of mean Waterbird Conservation Value (WCV) scores for 11 sites and 65 waterbird species in southern Africa during January. Data on which the scores are based were sourced from International Waterbird Census database, Wetlands International (T. Langedoen *in litt.*).

Species	Wetlands International Site Code										
	BW00056	NA00031	NA00033	NA00034	BW00081	BW00094	NA00041	ZA00429	NA00046	ZA00019	ZA00469
African Black Oystercatcher	0.00	0.00	0.17	0.00	0.00	0.00	0.35	0.00	1.61	0.40	0.00
African Darter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
African Sacred Ibis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06
African Spoonbill	0.70	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.03	0.09
Bar-tailed Godwit	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.11	0.09	0.00
Black Tern	0.00	0.00	0.04	1.38	0.00	0.00	0.30	0.00	1.48	0.00	0.00
Black-necked Grebe	0.00	0.00	0.09	0.00	0.00	0.00	4.64	0.00	15.10	0.00	0.25
Blacksmith Lapwing	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.05	0.00	0.00	0.02
Black-tailed Godwit	0.00	0.00	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-winged Pratincole	0.08	0.00	0.00	0.00	0.00	0.00	0.00	104.79	0.00	0.00	0.00
Black-winged Stilt	1.71	0.00	0.00	0.00	0.07	0.16	0.21	0.07	0.64	0.14	1.22
Cape Cormorant	0.00	0.00	15.52	0.51	0.00	0.00	17.72	0.00	2.44	0.10	0.59
Cape Shoveler	0.02	0.02	0.04	0.00	0.00	0.00	0.04	0.12	0.07	0.00	0.11
Cape Teal	0.16	0.15	0.12	0.00	0.00	0.23	0.18	0.02	0.56	0.00	0.14
Caspian Tern	2.91	6.20	1.65	0.00	0.07	0.33	0.13	2.18	4.04	0.69	3.01
Cattle Egret	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.05	0.00	0.00	0.00
Chestnut-banded Sandplover	4.08	10.08	5.15	0.00	0.07	0.00	0.37	0.00	23.59	0.33	0.77
Common Greenshank	0.03	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.06	0.16	0.11
Common Moorhen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Common Pratincole	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Common Ringed Plover	0.02	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.33	0.16	0.07
Common Tern	0.00	0.00	14.69	0.00	0.00	0.00	0.00	0.00	1.53	0.16	0.07
Common Whimbrel	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
Crested Tern (Swift tern)	0.00	0.00	1.06	0.00	0.00	0.00	0.49	0.00	3.89	1.28	1.04
Curlew Sandpiper	0.02	15.67	9.58	0.06	0.00	0.00	0.44	0.00	5.93	5.06	1.12
Damara Tern	0.00	0.84	0.65	0.03	0.00	0.00	0.12	0.00	1.82	0.00	0.00
Egyptian Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.01	0.01	0.06
Eurasian Curlew	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.02
Eurasian Golden Plover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00
Fulvous Whistling Duck	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.01	0.00	0.00	0.00
Glossy Ibis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Great Crested Grebe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
Great White Pelican	4.15	1.08	1.25	0.07	0.04	7.81	0.04	0.01	2.42	0.19	0.51
Greater Flamingo	3.14	19.13	5.78	1.45	6.58	78.86	1.63	0.00	20.06	0.73	1.48
Grey Heron	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Grey Plover	0.00	0.00	0.30	0.00	0.00	0.00	0.03	0.00	1.00	3.73	0.18
Grey-headed Gull	0.07	0.00	0.00	0.00	0.02	0.04	0.00	0.07	0.00	0.00	0.01
Hartlaub's Gull	0.00	0.00	0.21	0.01	0.00	0.00	1.53	0.00	2.27	1.65	1.80
Hottentot Teal	0.57	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.04	0.00	0.00
Kelp Gull	0.00	0.00	1.75	0.23	0.00	0.00	0.90	0.00	2.76	0.39	0.56
Kittlitz's Plover	0.90	0.00	0.00	0.00	0.22	0.02	0.00	0.84	0.06	1.14	3.63
Lesser Crested Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.12	0.00	0.00
Lesser Flamingo	16.99	26.11	5.45	0.00	166.67	20.73	1.78	0.00	18.23	0.00	0.40
Little Egret	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.02
Little Grebe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Little Stint	0.08	3.47	0.79	0.02	0.00	0.00	0.04	0.00	0.43	0.04	0.11
Little Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03
Marsh Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.08
Pied Avocet	7.58	0.00	0.08	0.00	0.26	1.31	0.51	0.00	6.88	0.24	0.46
Red Knot	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.08	0.55	0.00
Red-billed Teal	0.03	0.00	0.00	0.00	0.00	0.06	0.00	0.01	0.00	0.00	0.00
Red-knobbed Coot	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.02
Reed Cormorant	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
Ruddy Turnstone	0.00	0.00	0.66	0.00	0.00	0.00	0.54	0.00	1.63	1.68	0.00
Ruff	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Sanderling	0.00	14.12	4.35	0.00	0.00	0.00	0.09	0.00	5.74	1.27	0.02
Sandwich Tern	0.00	0.00	1.08	0.00	0.00	0.00	0.03	0.00	0.29	0.04	0.05
South African Shelduck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.35
Spur-winged Goose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.28
Three-banded Plover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Whiskered Tern	3.69	0.00	0.00	0.00	0.21	0.32	0.00	3.59	0.00	0.00	0.00
White-breasted Cormorant	0.60	0.00	5.49	0.25	0.00	0.00	2.73	0.50	5.10	0.14	2.08
White-fronted Plover	0.20	0.00	5.40	0.14	0.00	0.02	0.10	0.00	6.23	1.21	0.05
White-winged Tern	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Yellow-billed Duck	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.25	0.00	0.07	0.32
No. species at 1% level	**8.00**	**8.00**	**15.00**	**2.00**	**2.00**	**4.00**	**6.00**	**3.00**	**21.00**	**8.00**	**8.00**
Total WCV Score	**47.83**	**96.87**	**84.06**	**4.14**	**174.22**	**110.21**	**34.99**	**113.72**	**137.78**	**22.10**	**21.45**

Appendix 2.4 List of 137 wetland sites in western Europe used in the case study in this chapter. The Ref No. should be used for Figures 2.2 and 2.3. WI Site code refers to the code used by Wetlands International as a reference code for wetland sites in the International Waterbird Census.

Ref. No.	WI Site Code	Country	WI Site name	No. of surveys	Latitude	Longitude
1	BE01026	Belgium	Belgium (entire country)	41	50.6600	4.6300
2	DK00047	Denmark	Danish Wadden Sea	45	55.1700	8.5800
3	DK00163	Denmark	Lolland NW	21	54.9200	11.5000
4	DK00221	Denmark	Roskilde Fjord	21	55.5800	12.0800
5	DK00264	Denmark	Sydfynske Hav	16	55.0000	10.5000
6	FR00088	France	Autres sîtes- 86 Vienne	26	46.4995	0.1671
7	FR00109	France	Baie de l'Aiguillon et pointe d'Arcay	78	46.2728	-1.1765
8	FR00123	France	Baie du Mont Saint Michel	77	48.6447	-1.6144
9	FR00139	France	Bassin d'Arcachon	70	44.6780	-1.1354
10	FR00167	France	Cours du Rhin (67/68)	38	48.2899	7.6861
11	FR00212	France	Etangs de la Brenne	44	46.9120	1.1807
12	FR00258	France	Etangs Montpellierains (34&30)	44	43.5682	3.9676
13	FR00266	France	Golfe du Morbihan	80	47.6615	-2.7462
14	FR00285	France	La Camargue	46	43.6235	4.3593
15	FR00299	France	Lac de Grandlieu	41	47.0919	-1.6803
16	FR00314	France	Lac du der-Chantecoq (51/52)	43	48.5688	4.7790
17	FR00319	France	Lac Léman-F	40	46.3886	6.3986
18	FR00334	France	Littoral Picard	44	50.3721	1.5824
19	FR00341	France	Loire Aval	43	47.2397	-1.8390
20	FR00382	France	Presqu'île Guérandaise dont Traicts du Croisic	44	47.4033	-2.2541
21	FR00394	France	Résèrve Naturelle de Moeze (Charente-Seudre)	44	45.8939	-1.1441
22	FR00463	France	Salins de Giraud & d'Aigues-Mortes	3	43.3640	4.7350
23	DE00116	Germany	Arendsee	6	52.8913	11.4757
24	DE00262	Germany	Bodensee-Obersee-D	40	47.6169	9.4606
25	DE00263	Germany	Bodensee-Untersee-D	40	47.7050	9.0108
26	DE00390	Germany	Donau: km 2246-2406	22	48.8333	12.8500
27	DE00431	Germany	Dümmer: See mit Nord- und Südufer	4	52.5136	8.3356
28	DE00785	Germany	Greifswalder Bodden: Silmenitz - Fähre Glewitz	1	54.2268	13.4089
29	DE02114	Germany	Rhein: Nonnenweier - Kehl	34	48.4600	7.7700
30	DE02799	Germany	Wattenmeer SH 06	25	54.9200	8.3333
31	DE02800	Germany	Wattenmeer SH 07	25	54.7300	8.4900
32	DE02801	Germany	Wattenmeer SH 08	25	54.6300	8.7800
33	DE02802	Germany	Wattenmeer SH 09	25	54.5333	8.5400
34	DE02803	Germany	Wattenmeer SH 10	25	54.4000	8.8167
35	DE02804	Germany	Wattenmeer SH 11	25	54.2400	8.7500
36	DE02805	Germany	Wattenmeer SH 12	24	54.0600	8.8000
37	DE02806	Germany	Wattenmeer SH 13	25	53.9600	8.9000
38	IE00148	Ireland	Cork Harbour	14	51.8514	-8.2903
39	IE00192	Ireland	Dublin Bay	14	53.3424	-6.1831
40	IE00195	Ireland	Dundalk Bay	14	53.9402	-6.3156
41	IE00490	Ireland	Shannon & Fergus Estuary Aerial	6	52.6134	-9.1812
42	IE00555	Ireland	Wexford Harbour & Slobs	13	52.3332	-6.4448
43	IT00036	Italy	Baia di Panzano	15	45.9560	13.4385
44	IT00137	Italy	Delta del Po - parte veneta	11	44.9910	12.4180
45	IT00304	Italy	Laghi di Lesina e Varano	13	41.9112	15.2777
46	IT00365	Italy	Lago di Garda	15	45.1456	9.9414
47	IT00445	Italy	Laguna di Caorle e Valli di Bibione	14	45.5399	12.2425
48	IT00446	Italy	Laguna di Grado e Marano	12	45.7333	13.2500
49	IT00447	Italy	Laguna di Venezia	14	45.8286	12.7981
50	IT00494	Italy	Manfredonia	13	41.8836	15.6203
51	IT00535	Italy	Orbetello e Burano	16	42.7424	11.0209
52	IT00536	Italy	Oristano	14	40.1216	8.9055
53	IT00640	Italy	Stagno di Cagliari	14	39.2612	9.5760
54	IT00670	Italy	Trani	5	40.3023	17.7781
55	IT00671	Italy	Trasimeno	16	43.1985	12.5915
56	IT00696	Italy	Valli di Comacchio e Vene di Bellocchio	12	44.7569	11.8431
57	PT00063	Portugal	Estuário do Tejo	32	38.8000	-9.0000
58	ES00017	Spain	Aiguamolls de l´Emporda (GI)	15	42.1970	3.1030
59	ES02188	Spain	Albufera de Valencia (V)	15	39.3170	-0.3550
60	ES00071	Spain	Arrozales de Isla Mayor e Isla Mínima (SE)	3	40.3000	-3.7500
61	ES00642	Spain	De la Algaida a Hato Villa (H)	15	36.8000	-2.6000
62	ES00652	Spain	Delta del Ebro (T)	16	40.6990	0.8040
63	ES01154	Spain	Embalse de Sierra Brava (CC)	5	39.1790	-5.6430
64	ES01453	Spain	Graveras de El Porcal (M)	16	40.2910	-3.5270
65	ES01554	Spain	La Nava de Santullán	2	40.3000	-3.7500
66	ES01614	Spain	Laguna de Boada (P)	1	41.9690	-4.8970
67	ES01970	Spain	Lagunas de Villafáfila (ZA)	16	41.8160	-5.6050

Appendix 2.4 contd

Ref. No.	WI Site Code	Country	WI Site Name	No. of surveys	Latitude	Longitude
68	ES02018	Spain	Los Pobres. Lucios de Beta La Plama (consolidated)	6	36.9270	-6.2380
69	ES02052	Spain	Marisma de Hinojos (H)	14	36.9760	-6.3820
70	ES02068	Spain	Marismas del P.N. Bahía de Cádiz (CA)	1	36.5333	-6.2667
71	ES02072	Spain	Marismas P.N. Bahía de Cádiz	4	36.5333	-6.2667
72	ES02184	Spain	Parque Nacional de Doñana (consolidation)	5	37.0110	-6.3520
73	ES02035	Spain	Veta La Palma (SE)	15	36.9270	-6.2380
74	CH00021	Switzerland	Bodensee-Obersee-CH	43	47.5828	9.3661
75	CH00022	Switzerland	Bodensee-Untersee-CH	43	47.6778	9.0233
76	CH00074	Switzerland	Lac de Neuchâtel	43	46.8956	6.8350
77	CH00079	Switzerland	Lac Léman-CH	43	46.4719	6.6964
78	CH00135	Switzerland	Vierwaldstättersee	43	47.0100	8.3986
79	CH00146	Switzerland	Zürichsee	43	47.2231	8.7061
80	NL00194	The Netherlands	BiesboschMON61	34	51.7658	4.7614
81	NL00141	The Netherlands	Gelderse PoortMON08	34	51.8764	6.0191
82	NL00154	The Netherlands	Gestuwde MaasMON21	34	51.7500	5.8021
83	NL00155	The Netherlands	Getijde-beinvloede MaasMON22	34	51.7532	5.1731
84	NL00136	The Netherlands	GrevelingenMON03	22	51.7367	3.9942
85	NL00168	The Netherlands	HaringvlietMON35	34	51.7856	4.2063
86	NL00156	The Netherlands	IJsselmeerMON23	34	52.7682	5.3769
87	NL00142	The Netherlands	IJsselMON09	34	51.9947	6.0129
88	NL00202	The Netherlands	KrimpenerwaardMON69	34	51.9538	4.7190
89	NL00157	The Netherlands	MarkermeerMON24	34	52.5322	5.2122
90	NL00153	The Netherlands	Midden-Limburgse MaasplassenMON20	34	51.1540	5.9132
91	NL00233	The Netherlands	Noordzee benoorden de WaddenSEA02	27	53.4889	5.6077
92	NL00135	The Netherlands	Noordzee benoorden WaddenMON02	34	53.4200	5.3358
93	NL00137	The Netherlands	OosterscheldeMON04	22	51.5825	3.9512
94	NL00222	The Netherlands	other sites in FrieslandMONFR	34	52.8126	5.8886
95	NL00223	The Netherlands	other sites in GelderlandMONGL	34	52.1969	5.7919
96	NL00224	The Netherlands	other sites in GroningenMONGR	34	53.3170	6.7065
97	NL00226	The Netherlands	other sites in Noord-BrabantMONNB	34	51.5463	5.1148
98	NL00227	The Netherlands	other sites in Noord-HollandMONNH	34	52.3453	4.8915
99	NL00228	The Netherlands	other sites in OverijsselMONOV	34	52.4136	6.4556
100	NL00229	The Netherlands	other sites in UtrechtMONUT	34	52.0835	5.2107
101	NL00231	The Netherlands	other sites in ZeelandMONZL	34	51.2788	3.7994
102	NL00230	The Netherlands	other sites in Zuid-HollandMONZH	34	51.6826	4.3377
103	NL00169	The Netherlands	VolkerakmeerMON36	34	51.6452	4.2828
104	NL00140	The Netherlands	VoordeltaMON07	22	51.6054	3.6731
105	NL00149	The Netherlands	Waal: Nijmegen - WaardenburgMON16	34	51.8987	5.5667
106	NL00134	The Netherlands	WaddenzeeMON01	34	53.4303	5.9560
107	NL00232	The Netherlands	WaddenzeeSEA01	27	53.4344	5.9791
108	NL00139	The Netherlands	WesterscheldeMON06	22	51.3748	3.8977
109	NL00014	The Netherlands	Wonseradeel en WorkumGSC114	136	52.9043	5.4432
110	GB00101	United Kingdom	Alt Estuary	41	53.5167	-3.0500
111	GB00525	United Kingdom	Blackwater Estuary: Total	44	51.7167	0.8000
112	GB00675	United Kingdom	Breydon Water & Berney Marshes	43	52.6000	1.6833
113	GB01020	United Kingdom	Chichester Harbour	43	50.7833	-0.9000
114	GB01364	United Kingdom	Dee Estuary (England and Wales)	44	53.2667	-3.1000
115	GB01817	United Kingdom	Forth Estuary	44	56.0000	-3.2667
116	GB02086	United Kingdom	Hamford Water	5	51.8667	1.2333
117	GB02087	United Kingdom	Hamford Water and Naze Combined	41	51.8667	1.2333
118	GB02329	United Kingdom	Humber Estuary	44	53.5333	-0.1333
119	GB02369	United Kingdom	Inner Moray and Inverness Firth	44	57.5333	-4.2000
120	GB02609	United Kingdom	Langstone Harbour	44	50.8167	-1.0000
121	GB02674	United Kingdom	Lindisfarne	44	55.6667	-1.8167
122	GB03356	United Kingdom	Loughs Neagh & Beg	27	54.6167	-6.4167
123	GB03508	United Kingdom	Medway Estuary	44	51.4000	0.6500
124	GB03535	United Kingdom	Mersey Estuary	44	53.3000	-2.8167
125	GB03644	United Kingdom	Morecambe Bay	44	54.1167	-2.9167
126	GB03790	United Kingdom	North Norfolk Coast	44	52.9833	0.7500
127	GB03897	United Kingdom	Ouse Washes	44	52.5167	0.2500
128	GB04224	United Kingdom	Ribble Estuary	44	53.7167	-2.9167
129	GB04908	United Kingdom	Severn Estuary	44	54.8000	-2.5000
130	GB05017	United Kingdom	Solway Estuary	44	54.9167	-3.4000
131	GB05021	United Kingdom	Somerset Levels	43	51.1500	-2.9833
132	GB05042	United Kingdom	South Lancashire Mosses (Geese)	1	53.6167	-2.8833
133	GB05193	United Kingdom	Stour Estuary	44	51.9333	1.1500
134	GB05205	United Kingdom	Strangford Lough	38	54.5000	-5.6000
135	GB05261	United Kingdom	Swale Estuary	44	51.3500	0.8333
136	GB05353	United Kingdom	Thames Estuary	44	51.4833	0.5667
137	GB05382	United Kingdom	The Wash	43	52.9333	0.3000

Appendix 2.5 List of 22 wetland sites in western Africa used in the case study in this chapter. The Ref No. should be used for Figures 2.2 and 2.3. WI Site code refers to the code used by Wetlands International as a reference code for wetland sites in the International Waterbird Census.

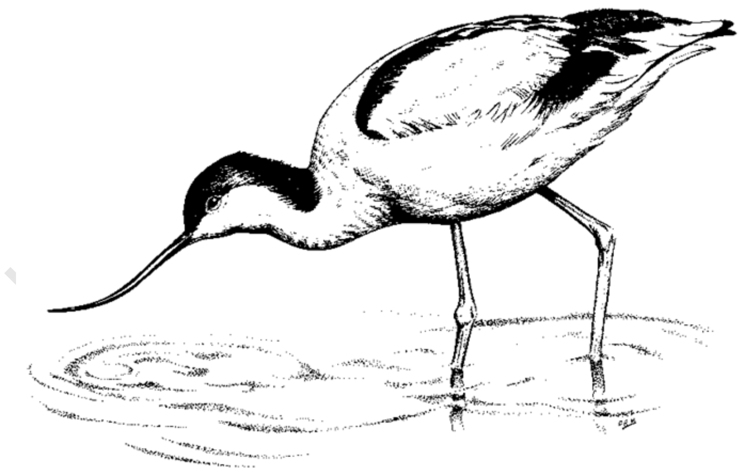
Ref. No.	WI Site Code	Country	WI Site Name	No. of surveys	Latitude	Longitude
138	BF00006	Burkina Faso	Lake Oursi-Lake Darkoye	1	0.0800	14.7000
139	CM00007	Cameroon	Bas Chari (Cameroun)	2	12.6353	14.8061
140	CM00023	Cameroon	Lac Tchad - quadrat 101	1	12.3333	14.5000
141	CM00026	Cameroon	Lac Tchad (Cameroon)	1	12.8371	14.2936
142	CM00055	Cameroon	Waza Logone Floodplain	2	11.0184	14.7343
143	GH00003	Ghana	Keta Lagoon complex	11	5.8996	0.9085
144	GN00010	Guinea	Vasieres de Khonibenki et Yongo Sale	4	10.4391	-14.5507
145	MR00005	Mauritania	Bell	4	16.3272	-16.3839
146	MR00012	Mauritania	Lac d Aleg	1	17.0833	-13.9833
147	MR00015	Mauritania	Lac Rkiz	3	16.8459	-15.3064
148	MR00019	Mauritania	Mahmouda	2	16.3660	-7.6870
149	MA00022	Morocco	Baie d'Ad Dakhla	5	23.6500	-15.8700
150	MA00147	Morocco	Merja Zerga plus Roosts	17	34.8000	-6.3000
151	MA00148	Morocco	Merja Zerga: Kenitra	20	34.8000	-6.3000
152	NE00033	Niger	Mare de Albarkaize	2	12.0842	3.2265
153	NE00035	Niger	Mare de Dole	2	14.1756	11.1799
154	NE00038	Niger	Mare de Guiwana	1	13.5164	2.1157
155	NG00001	Nigeria	Baturiya Complex	3	12.3372	10.1561
156	NG00011	Nigeria	Lac Tchad/Nigeria	1	12.9159	13.9506
157	SN00019	Senegal	Ndiael	25	16.2333	-16.0833
158	SN00025	Senegal	Parc National des Oiseaux du Djoudj	5	16.4167	-16.2500
159	SN00026	Senegal	Parc National du Delta du Saloum	2	13.6331	-16.5674

Appendix 2.6 List of 11 wetland sites in southern Africa used in the case study in this chapter. The Ref No. should be used for Figures 2.2 and 2.3. WI Site code refers to the code used by Wetlands International as a reference code for wetland sites in the International Waterbird Census.

Ref. No.	WI Site Code	Country	WI Site Name	No. of surveys	Latitude	Longitude
160	BW00056	Botswana	Nata Sanctuary	13	-20.3333	26.0833
161	NA00031	Namibia	Sandwich Harbour Total	4	-23.3580	14.4683
162	NA00033	Namibia	Sandwich Harbour: southern wetlands	19	-23.4175	14.4625
163	NA00034	Namibia	Sandwich Harbour: Western SandSpit	4	-23.4102	14.4353
164	BW00081	Botswana	Sua Pan	4	-20.6565	25.9832
165	BW00094	Botswana	Sua Spit Natural Reserve	3	-20.8133	25.4217
166	NA00041	Namibia	Swakopmund Saltworks	12	-22.5888	14.5166
167	ZA00429	South Africa	Vaal Dam: South	3	-27.0200	28.1800
168	NA00046	Namibia	Walvis Bay Ramsar Site	27	-22.9943	14.4476
169	ZA00019	South Africa	Berg River	18	-32.7788	18.1488
170	ZA00469	South Africa	Langebaan Lagoon	32	-33.1409	18.0558

Chapter 3

Further applications of the Waterbird Conservation Value score: visual analyses through time



Abstract

Analyses of waterbird census data has traditionally focussed on species composition and abundance, particularly species reaching the 1% threshold levels. In this chapter I explore additional aspects of the Waterbird Conservation Value (WCV) score using data drawn from long-term waterbird surveys from four representative wetlands in the winter-rainfall region of South Africa. Wetlands included two artificial sites (a sewerage treatment works and farm dam), and two natural sites (coastal lakes). I use visual analytics (colour-coded histograms and radar graphics) to explore how WCV score outputs for each site provide ways in which to assess waterbird conservation priorities. Assessments were based on species composition, priority species, and temporal fluctuations and importance. Emphasis is placed on the visual assessment of patterns, sporadic influxes and the conservation implications of the generated outputs. The overall site conservation significance at a regional level is discussed in light of the flyway level approach discussed in Chapter 1. The conservation assessments are then discussed in light of the wetlands, their habitats and associated waterbird communities. Recommendations are made to apply and refine the WCV score and associated graphical outputs within the national waterbird monitoring programme in South Africa in order assess waterbird conservation priorities in the country.

Introduction

The development of the Waterbird Conservation Value (WCV) score and a case study to demonstrate its application were undertaken in Chapter 2. The case study provided valuable insight into how this new method provided an improved waterbird conservation assessment at a flyway level. But in what other ways can the WCV score be considered and applied?

Tufte (1983) explored ways in which scientific data could be visually assessed. His widely recognised book on the theory and design of data graphics showed that results from large-scale and long-term data collection studies could be better interpreted when presented graphically rather than using the standard tabular formats and statistical procedures. Using visual outputs, Tufte (1983) formulated methods to display data for precise, effective and quick communication analysis. His basic principles cover aspects such as efficient design, content rich data representations and the presentation of information in a non-redundant way. Application of data visualization is also used in other sectors. Centrifuge Systems Inc. (http://www.centrifugesystems.com/), a fraud analysis and cyber security company, supports Tufte's (1983) concepts and has employed interactive data visualization in their system analyses. Their outputs have provided valuable tools combining agile data integration, dynamic relationship mapping, and interactive visual analytics to reveal insights in big data (Centrifuge Systems 2008, 2012). Using visualizations and link intelligence, Centrifuge Systems analysts have improved fraud detection and pharmaceutical risk analyses (Centrifuge Systems 2008).

This chapter explores additional aspects of the WCV score using data from waterbird counts from selected wetlands in the Western Cape, South Africa. The primary focus is on the use of graphical outputs to assess priority species, temporal importance and fluctuations, and determine overall site conservation significance. Emphasis will be on the visual assessment of patterns and the conservation implications of the generated outputs. The conservation assessments are then discussed in light of the wetlands, their habitats and associated waterbird communities.

Methods

Four wetland sites were selected from the Western Cape, South Africa, to illustrate the analyses: Rocher Pan, Droëvlei Dam, Paarl Waste Water Treatment Works and De Hoop Vlei (Figure 1.4 in Chapter 1). These sites were selected based on (a) their geographic location in the winter rainfall region of South Africa, (b) their different inundation patters and (c) the availability of long-term, monthly waterbird surveys which had been undertaken at each site. The winter rainfall region is described in Chapter 1. To meet the objectives of this chapter, the results presented here are a synthesis of relevant outputs of detailed analyses for each site (Appendices A, B, C and D).

Waterbird census data for the five selected sites were sourced from the Coordinated Waterbird Counts programme (CWAC, Animal Demography Unit, unpubl. data) and from CapeNature, the provincial conservation authority in the Western Cape Province. At each site, a minimum of 10 years census period was selected for each site: Rocher Pan (September 1985–June 2004), Droëvlei Dam (November 1982–March 1990), Paarl Waste Water Treatment Works (May 1994–June 2004) and De Hoop Vlei (June 1984–September 2006).

WCV scores were calculated as described in Chapter 2. However, the scores were computed for each monthly survey, rather than on averaged data, as in Chapter 2. Seasonal scores were also computed to provide a measure of the conservation importance of the site during summer and winter. For the winter rainfall region, I defined summer as October–March and winter as April–September (Chapter 1). Priority species were determined for each site based on WCV scores. Scores equal or greater to 1 were identified as globally important (Ramsar and Global IBA) species and scores greater or equal to 0.5 but less than 1 as regionally important (Sub-regional IBA) species; the latter was identified as a criterion for designating southern Africa sub-regional IBAs (Barnes 1998).

Results for the WCV score analyses are presented graphically in the form of colour-coded histograms and radar plots. Generalised linear models (GLMs) were used to determine the relationship between the WCV score and proportion of 1% threshold species and total abundance. Scatterplots were used to display the results graphically. Discussion of the results are dealt with under each result heading and not separately after presentation of the results; this was done to help provide clarity for each of the results obtained.

Results and discussion

Monthly WCV scores and priority species

The monthly WCV scores and species contributions to the WCV score for each site are given in Figures 3.1, 3.2, 3.3 and 3.4. Scores generally fluctuated widely at all sites between months and between years. The largest mean WCV score was recorded at De Hoop Vlei (6.49) with Droëvlei Dam recording the smallest mean WCV score (1.01) (Table 3.1). The WCV scores at Rocher Pan showed a strong seasonal pattern

(Figure 3.1); none of the other sites' scores revealed any seasonality of occurrence. Rocher Pan is an ephemeral wetland with annual wet/dry periods (Appendix C) and this strongly influences the occurrence of waterbirds at this wetland; the other sites tend to hold water throughout the year. Droëvlei Dam (Appendix B) and De Hoop Vlei (Appendix D) and have been known to dry out completely in summer, but not on an annual basis, as happens at Rocher Pan (Appendix C).

The colour-coded histograms show the composition of species making the greatest contributions (i.e. equal to or greater than a score of 1.0) to each monthly WCV score. Consequently species patterns were easily noticeable and dominant species easily recognisable: Cape Shoveler at De Hoop Vlei, Hartlaub's Gull at Paarl WWTW, Maccoa Duck at Droëvlei Dam and equal proportions of White-breasted Cormorant and Cape Shoveler at Rocher Pan. The colour-codes for each of the priority species also revealed changes in contributions to WCV scores at each site during the respective study periods. For example, at De Hoop Vlei, large populations of Cape Shoveler (orange shading, Figure 3.4) were recorded regularly from August 1985–January 2001, but it was evident that from February 2001 numbers started to decline as was evidenced by their WSC scores dropping below 1.0. Other examples included Greater Flamingo (light pink shading) at Paarl WWTW (Figure 3.3) which occurred fairly regularly from May 1994–1999 but with no records post 1999, and White-breasted Cormorant (brown shading) and Cape Shoveler (orange shading) at Rocher Pan (Figure 3.1) whose numbers declined substantially after 1995.

The variability of the contributions by individual species to WCV scores also becomes apparent through the histograms. Effectively, there is a signature for each species. Even quite large variations in numbers at a single site of a species with a large flyway population (and therefore 1% level) make little impression on the WCV score histogram. This is because the denominator, the 1% level, is large. However, if the variability in numbers for a species is large relative to the flyway population, it will immediately be apparent in these histograms. The histograms therefore highlight the relative variability of the 'important species'. This variability translates into defining the important periods or seasons during which these important species occur. Thus the colour-codes allow for patterns of variability for the WCV score of each species to be easily visible. For example, at all four sites Pied Avocet (blue shading) showed larger WCV score contributions during specific months; this reflects its known nomadic habits in southern Africa (Tree 1997). Other species which showed these irregular but large contributions to the WCV score included Caspian Tern (green shading) at De Hoop Vlei and Rocher Pan, Greater Flamingo (light pink shading) at De Hoop Vlei, and Swift Tern (dark green shading) at Rocher Pan (Figures 3.1). These sporadic peaks may (e.g. Pied Avocet) or may not (e.g. Caspian Tern) show annual patterns, nevertheless their contributions to the WCV score at these times highlights the conservation value of these species at a site at a specific, usually limited, time during the annual cycle.

Large seasonal contributions to the WCV score were made regularly for certain species. At Droëvlei Dam, Black-necked Grebe (dark red shading) contributed more to the WCV score during early summer (November–January), and Yellow-billed Duck (yellow shading) during late summer (March–April) (Figure 3.2). Cape Shoveler scores at Rocher Pan were greatest in early summer while at De Hoop Vlei they showed a strong late summer peak (Figures 3.1 and 3.4). Black-winged Stilts (black shading) made larger contributions in winter at Paarl WWTW (Figure 3.3) compared with early summer (November–January) at Rocher Pan (Figure 3.1). Most of the seasonal occurrence patterns based around the WCV scores relate to post-breeding moult congregations of waterfowl species. These are described and discussed in each of the site papers (Appendices A–D).

The relationships between the WCV scores and the number of species reaching 1% threshold levels are shown for each of the four sites in Figures 3.5a–3.5d. The scatterplots reveal stronger relationships at the coastal sites (Rocher Pan, and De Hoop Vlei) compared with the inland sites (Paarl WWTW and Droëvlei Dam). Coastal sites also showed higher overall WCV scores than inland scores; mean seasonal scores for Rocher Pan, and De Hoop Vlei were greater than 15 compared with Paarl WWTW and Droëvlei Dam which had mean WCV scores of less than 10 (Figures 3.5a–3.5d). The reason for this disparity is probably due to the coastal sites (a) being larger, (b) supporting more habitats and (c) able to support greater number of waterbirds. Rocher Pan and De Hoop Vlei are well known non-breeding sites for migrating shorebirds (Scolopacidae) and terns (Sternidae), and significantly large numbers of these species groups occur at these sites during the austral summer. Both Rocher Pan and De Hoop Vlei also act as local refuges for various waterfowl species, particularly during summer.

When comparing the relationship between the WCV scores and total abundance at each site (Figures 3.6a–3.6d) with the 1% threshold species, it was clear that, overall, these relationships were weaker. This strongly suggests that the WCV score is dependent more on the number of species reaching 1% levels than the total number of birds counted at a site. Total abundance does however play a role in determining species population levels at a site which is critical in separating out the priority versus non-priority species.

Interestingly the largest WCV score for Paarl WWTW occurred when only a single species (Hartlaub's Gull) reached the 1% threshold (WCV score of 3.53, Figure 3.3). This highlighted the importance of a single species to the overall score at a site. Droëvlei Dam highlighted that in the absence of globally important species the waterbird conservation value reached similar levels even when a single 1% threshold species was present. Thus the combined contributions of all waterbird species had the same or similar value as that of the contribution made by a single species which had 1% or more of its global population present at the site. The remaining sites tended to show that larger WCV scores occurred when there were at least two species at the 1% level but that there was overlap at all levels. For these sites, large concentrations of a few species made larger contributions to the score, although there were exceptions (Figures 3.5a–3.5d). There were occasions when there were no 1% level species present but the overall WCV score was similar to that when two or three species reached 1% levels. This suggested that counts of species were more evenly spread at these times and therefore made a significant contribution to the overall waterbird conservation value at that site.

Variation around the linear regression

WCV scores varied at particular threshold levels, particularly for the larger sites; the smaller sites did not show as large variation and this is possibly due to the fact that they exhibited smaller, overall WCV scores. For example, at Rocher Pan, when two species reached 1% levels WCV scores ranged from 3.98 to 13.86 (Figure 3.5a), a difference of 9.88 at this level. Similar variability occurred at De Hoop Vlei (6.16–16.66, diff. = 10.5, level 3, Figure 3.5c). For all sites these differences relate to species' variation in abundance (i.e. different species contribute to the WCV score at different times). A single species can either make an extra-ordinary large contribution to the score or two species can make equal or similar contributions. These contributions are related to the ratio of the 1% threshold level to the number of individuals present for a species (i.e. a species individual CV score). For example, in southern Africa, the Caspian Tern has a 1% level of 15; if 100 individuals are observed the resultant score is high (6.67). In comparison, White-breasted Cormorant has a 1% level of 120, so if 100 individuals are observed the resultant score (0.83) is considered low. When the number of waterbirds observed is less than the 1% threshold, WCV scores are less than one. Ultimately the WCV score is dependent on the estimated population size which then determines the 1% level. From data presented in this thesis (this chapter and Appendices A–D), and from other studies (Anderson et al. 2003, Bamford and Watkins 2005, Moores 2006, Bamford et al. 2008), waterbird occurrence and abundance at any given wetland can be extremely variable from one year to the next depending on factors such as amount of inundation, water depth, food availability and extent of other fringing habitats for roosting and breeding. This annual variability will influence 1% levels at a site which determine the WCV score and hence its conservation importance.

However, the WCV score does put the interpretation of waterbird count data and the conservation value of a wetland into a new perspective. A new concept to emerge from this is that sites do not necessarily require individual species to meet the 1% threshold levels in order to make them conservation worthy. Each species' contribution to the score is valuable with some species contributing more and therefore will have greater value.

Seasonal WCV scores

Mean monthly summary WCV scores for each site are given in Figure 3.7 and Table 3.2. Mean WCV scores varied considerably through the year across all sites; Rocher Pan scores fluctuated the most during the year while De Hoop Vlei showed less variation. Droëvlei Dam and Paarl WWTW showed more constant scores throughout the year.

Some sites had similar WCV scores at specific times of the year. For example, Rocher Pan and De Hoop Vlei had similar scores from November–December and from July–August but from January to June their scores differed considerably (Figure 3.7, Table 3.2). There were times (February) when Droëvlei Dam and Rocher Pan had similar WCV scores. Thus despite the relative size of each wetland and vastly different wetland types each site had equal conservation value or importance. Paarl WWTW was the only site which had its largest WCV score in winter (June); all other sites had summer WCV peaks: Rocher Pan in October, Droëvlei Dam in January, and De Hoop Vlei in February.

Application and conservation value of the WCV score

Overall, there is a clear separation in the way that waterbird species respond at each of the four sites (Table 3.2). This provides strong evidence for preferred site selection by certain species. Species with high WCV scores at sites will tend to favour that site over others. Monthly data have shown how changes in the WCV score help assess the conservation value on both a survey-by-survey and seasonal basis. Thus a wetland becomes important for a different suite of species at varying stages throughout the year and could provide evidence for inter-connectivity between wetlands. Seasonal WCV scores could also help identify sites that have a regular seasonal influx of waterbirds;

changes in seasonal patterns of abundance for the whole waterbird community and for priority species can then be identified.

But what conservation value does the WCV score have for these sites and how relevant are regional WCV scores compared with flyway level values discussed in Chapter 1? By using the WCV score, the significance of local species populations and site evaluation can be assessed at the waterbird community level and not solely for species reaching 1% threshold levels. This places a strong conservation value on the entire wetland avifauna and focuses attention on how waterbird populations use wetlands at a regional scale. Priority species can be identified rapidly at sites and changes in their WCV scores over time can provide important trends from which alert systems can be put in place if populations suddenly start declining. Monitoring of wetland characteristics and changes to habitats are important covariates that need to be monitored or assessed in order to draw appropriate conclusions from the WCV score.

These results highlight how the value of a wetland can be assessed relatively quickly based on a single score both at a site scale and at species levels. Thus intra- and inter variability can be gauged and comparisons made seasonally within a site and between sites. It is important to bear in mind that the score cannot be seen in isolation but should be considered as part of the entire ecology and functioning of a wetland system, i.e. annual water level fluctuations, extent of habitats and availability of food. These all impact on the occurrence and abundance of waterbirds at any given wetland.

Flyway versus regional evaluation

In Chapter 1, flyway WCV scores enabled evaluation of different sites throughout the East Atlantic flyway region. Site and species scores fluctuated within each region and between regions. From a species perspective, however, the WCV score at this scale has value for evaluation of migrant species, particularly during different stages of their annual migratory cycle and across different bio-regions. The WCV score can therefore be used as a tool to explore annual changes of flyway populations and formulate guidelines for setting future conservation priorities.

In contrast, regional evaluation as described in this chapter, tends to have greater relevance for resident species, although it does also allow for migrant scores to be assessed and evaluated. Regional WCV scores help to evaluate the roles individual sites play within a defined geographical, vegetative and climatological area. Thus, the sites selected for this chapter have relevance to a specific bio-climatic zone – the winter rainfall region of South Africa – a region in which wetlands have not been cumulatively assessed at the broader landscape level (Chapter 1). It is important that wetlands should not be seen in isolation but as forming a critical network for waterbirds in the landscape (this is further explored in Chapter 5). Since evaluation of sites at regional level usually take place at country level attention is focused on resident species, a 'group' for which national or regional (provincial) environmental agencies are responsible. Thus regional WCV score computation will benefit local waterbird conservation initiatives and help drive regional and national waterbird conservation priorities.

Both flyway and regional application of the WCV score have conservation benefits and complement each other. Migrant species and local species are equally assessed albeit at different scales and, importantly, the WCV scores can be compared across these different spatial scales. Historically, conservation directives have been largely focused on migrant shorebird species and for good reason – their annual survival is dependent on the extent and protection of suitable wetlands along the length of the flyway. At the flyway level, then, the consistent application of the WCV score will assist in assessing the importance of sites on an annual basis. From this, international cooperation will be needed to ensure site protection. But what about local, resident species? In South Africa, at least, there has been limited focus placed on conservation directives of resident waterbirds (Chapter 1), especially endemics and breeding endemics, something that could be addressed through introduction of the WCV score approach. This could easily be implemented and applied within other countries or regions to set national or regional waterbird conservation priorities. Overall, the WCV score can be seen as an important and valuable tool that can be adapted at various levels to enhance the way in which conservation agencies and national governments can assess waterbird populations both globally and regionally.

Visual analytics as waterbird conservation tools

Data visualisation and presentation has been a primary focus of this chapter. The use of colour-coded histograms (Figures 3.2–3.5) and annotated radar plots (http://projects.gnome.org/gnumeric/doc/sect-graphs-overview-types-radar.shtml; Pedersen et al. 2002, Mann 2003) (Figure 3.7) have shown the benefits of using visual analytics as a useful tool in determining the conservation value of wetlands for waterbirds. The data presentation and outputs used have allowed visual comparisons to be made quickly and easily for large and long-term datasets, both at monthly and seasonal levels. Specifically, the benefits of the colour-coded histograms include:

- The overall conservation importance of the site is immediately noticeable. The histogram presents multiple data layers in a single graphical output, namely (a) overall WCV score, (b) species with WCV scores ≥1.0 (i.e. priority species),

(c) seasonality of priority species, and (d) population trends of priority species. It should be noted that in this study, Droëvlei dam and Paarl WWTW included species that reached the 0.5% threshold but which did not reach the 1% level. This was because few species reached the 1% threshold levels and to gauge Sub-regional IBA status, the 0.5% levels for southern Africa were used to assess the conservation value of the wetland. Based on this, it is suggested that sites which support few species meeting 1% threshold be assessed using the 0.5% levels, especially since the WCV score considers each species contribution to the overall score as important.

- Priority species are easily recognisable and their occurrence patterns are discernible at a glance. Each species generates a signature in the colour-coded histogram. In this regard, colours for species can be pre-determined for ease of comparison between sites and for familiarisation. Standardisation of species colours is particularly useful at regional or national level. At the flyway level, colour visualisation would be extremely valuable but this would require careful consideration in terms of the number of waterbird species for which colour-specificity would be required. It is important that colours are discrete and easily discernible to allow for ease of comparison. Nevertheless, the results from this study have shown the value of this colour-coded system in determining the conservation value of a wetland based on waterbird abundance patterns.
- Species with sporadic abundance peaks are easily noticed. This may require specific conservation action in terms of species using the site as a staging area or at certain times of the year.
- The combined contributions made by additional species are easily recognisable and often elucidates the important contributions made by these species to the overall WCV score.
- They assist in determining which months/seasons/periods the conservation significance for a species is greatest. From these temporal variations one can elucidate if occurrence patterns are noticeable.

The radar plot visualisation is a new and innovative way to display the conservation value of wetland sites on a temporal basis. The example described in this chapter used monthly survey data but other temporal data (quarterly and six-monthly) can easily be substituted in the radar graphic. However, less frequent surveys will provide coarser data outputs which would impact on the interpretation of the analyses.

Monthly surveys do provide better analysis of seasonality and are strongly encouraged as the minimum count frequency to be used in waterbird studies.

Can the WCV score tell us something about the wetland itself? Can it provide an indirect assessment of the state of the wetland? Based on the known ecological parameters or requirements for species or species groups the composition of the priority species could provide an indication of the health of a wetland. For example, if there were large numbers (larger than the 1% level) of pelicans and terns we could assume that fish availability was high; similarly large numbers of shorebird species (e.g. Curlew Sandpiper, Little Stint, Black-winged Stilt) would indicate that invertebrate prey was readily available. Changes in the abundance of priority species and/or the waterbird community itself would then indicate or infer changes in the structural composition of the wetland.

Concluding remarks

In terms of application of the WCV score, the above has shown how it can be used as a rapid conservation assessment tool. Waterbird ecologists and conservation authorities alike would greatly benefit from using this method to identify important sites and priority species. Using current information technology the WCV score can easily be incorporated as an algorithm into long-term waterbird datasets to gauge conservation importance. The conservation value can be assessed as survey data is added to the database. This would enable near real-time assessment of a site based on the accumulation of waterbird survey data, given that surveys can be carried out on a frequent basis. Visual outputs can be generated which will graphically illustrate the waterbird importance and value at a site.

Importantly and from a conservation perspective WCV scores can assess global and sub-regional IBA designation. Since the WCV score takes into account the relative contributions made by all species, and not only those of species reaching 1% threshold levels, I propose that the WCV score be considered as an alternative assessment tool for designating wetlands of international importance.

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Table 3.1 Summary information and count statistics for the four sites dealt with in this chapter and the Bot River Estuary in Chapter 4. WWTW = Waste Water Treatment Works, S = Summer, W = Winter. Species in bold are Red Data species (Barnes 2000) and those in italics are endemic to southern Africa (Hockey et al. 2005).

Description		Site name				
		Rocher Pan	Droëvlei Dam	Paarl WWTW	De Hoop Vlei	Bot River Estuary
Wetland type		Coastal lake	Farm dam	Waste Water Treatment Works	Coastal lake	Temporary closed estuary
Inundation, water quality		Ephemeral, brackish-freshwater	Permanent, freshwater	Permanent, freshwater	Mainly permanent, fresh to brackish	Permanent, brackish to saline
Size (ha)		260	30	72	750	1400
Conservation status		Protected	Unprotected	Partially protected	Protected	Partially protected
Total no. species		80	50	75	83	86
Mean abundance ± S.D.	S	3197.1 ± 2731.1	1935 ± 973.4	2821.8 ± 504.4	5710.2 ± 909.6	4558.9 ± 2664.1
	W	1534.2 ± 1730.3	791.9 ± 481	1650.9 ± 250.6	5203.9 ± 534.3	5265.6 ± 2759.8
Density[1] (birds/ha)	S	12.3	64.5	39.1	7.7	3.3
	W	5.9	26.3	22.9	6.9	3.8
Max. abundance	S	13 708	5701	5269	16 338	16 600
	W	9062	3002	2728	13 792	17 290
Mean Waterbird Conservation Value Score	S	6.03	1.52	2.64	6.49	6.83
	W	4.66	1.01	3.19	5.5	5.16
Threshold levels	1%[2]	14	3	6	16	13
	0.5%[3]	6	5	3	5	4
Number. of Red Data species		9	3	4	12	13
Top five abundant species (Max. count)		Red-knobbed Coot (6259) Curlew Sandpiper (5012) **Greater Flamingo (4239)** White-winged Tern (1662) *Cape Shoveler* (1619)	Ruff (920) Egyptian Goose (902) Little Stint (837) Red-knobbed Coot (837) White-winged Tern (590)	White-winged Tern (2796) Egyptian Goose (1341) **Lesser Flamingo** (1200) *Hartlaub's Gull* (1058) African Sacred Ibis (940)	Red-knobbed Coot (10801) Egyptian Goose (3175) Yellow-billed Duck (3005) *Cape Shoveler* (2542) Curlew Sandpiper (2467)	Red-knobbed Coot (15352) **Greater Flamingo** (2884) Common Tern (2351) Sandwich Tern 2059) Yellow-billed Duck (2030)

[1].Estimates based on mean abundance values

[2] Values are number of species reaching or surpassing the Ramsar (1%)

[3] Values are number of species reaching or surpassing the IBA Sub-regional (0.5%) but not surpassing the Ramsar 1% level

Table 3.2. List of priority species and their associated mean monthly and seasonal WCV scores for five selected sites in the Western Cape, South Africa. 'Additional species' refers to all other species which did not reach or surpass their respective 1% thresholds and represents the cumulative total of their individual WCV scores.

Site/Priority species	Month												Summer		Winter	
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Mean ±	S.D.	Mean ±	S.D.
Paarl WWTW																
Hartlaub's Gull	1.4	0.9	0.9	1.0	0.9	0.7	0.7	0.4	0.8	0.7	1.3	1.2	0.84	0.13	0.98	0.39
Black-winged Stilt	0.5	0.4	0.3	0.3	0.3	0.4	0.4	0.6	1.0	1.3	0.9	0.7	0.33	0.06	0.81	0.29
White-breasted Cormorant	0.3	0.3	0.2	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.4	0.3	0.23	0.07	0.40	0.12
Lesser Flamingo	0.0	0.4	0.4	0.2	0.2	0.1	0.0	0.0	0.1	0.2	0.0	0.0	0.20	0.16	0.05	0.07
Additional species	0.7	0.8	1.1	1.1	1.3	1.0	1.0	1.2	0.8	1.2	1.0	0.9	1.05	0.16	0.95	0.21
Total	**2.8**	**2.7**	**2.9**	**2.7**	**2.8**	**2.4**	**2.4**	**2.6**	**3.2**	**3.9**	**3.6**	**3.1**	**2.64**	**0.21**	**3.19**	**0.50**
Rocher Pan																
White-breasted Cormorant	0.68	1.18	1.18	2.34	1.81	0.54	0.05	0.00	0.23	0.81	0.64	0.52	1.18	0.83	0.48	0.30
Cape Shoveler	1.31	1.75	1.87	1.14	0.68	0.33	0.06	0.09	0.08	0.34	0.33	0.54	0.97	0.75	0.45	0.46
Greater Flamingo	1.16	1.11	0.94	0.75	0.19	0.07	0.02	0.03	0.01	0.02	0.11	0.47	0.51	0.48	0.30	0.46
Black-winged Stilt	0.98	1.57	1.03	0.33	0.08	0.06	0.02	0.02	0.03	0.07	0.13	0.30	0.52	0.64	0.25	0.37
Black-necked Grebe	1.23	0.85	0.29	0.06	0.00	0.00	0.00	0.00	0.02	0.09	0.30	0.81	0.20	0.34	0.41	0.50
Hartlaub's Gull	0.02	0.04	0.03	0.07	0.10	0.02	0.01	0.01	0.00	0.24	0.00	0.71	0.04	0.03	0.16	0.28
Pied Avocet	0.53	0.39	0.23	0.14	0.06	0.07	0.02	0.03	0.09	0.27	0.36	0.37	0.15	0.14	0.27	0.19
Swift Tern	0.04	0.08	0.12	0.07	0.19	0.09	0.03	0.00	0.06	0.13	0.09	0.11	0.10	0.06	0.07	0.05
Caspian Tern	0.02	0.14	0.13	0.03	0.05	0.15	0.06	0.00	0.01	0.01	0.00	0.00	0.09	0.05	0.01	0.01
Curlew Sandpiper	0.01	0.06	0.13	0.37	0.23	0.30	0.10	0.01	0.00	0.00	0.00	0.01	0.20	0.12	0.01	0.01
Lesser Flamingo	0.07	0.06	0.01	0.00	0.00	0.04	0.01	0.00	0.01	0.19	0.22	0.40	0.02	0.02	0.15	0.15
Kelp Gull	0.05	0.13	0.05	0.06	0.06	0.02	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.04	0.03	0.02
Yellow-billed Duck	0.23	0.19	0.10	0.08	0.04	0.03	0.04	0.06	0.11	0.27	0.23	0.25	0.08	0.06	0.19	0.08
Great Crested Grebe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional species	3.60	2.78	2.59	2.39	1.74	1.45	0.53	0.32	0.57	1.62	2.14	3.05	1.91	0.85	1.88	1.31
Total	**9.92**	**10.33**	**8.71**	**7.81**	**5.23**	**3.17**	**0.95**	**0.59**	**1.22**	**4.08**	**4.58**	**7.57**	**6.03**	**3.56**	**4.66**	**3.60**
Droevlei Dam																
Maccoa Duck	0.35	0.44	0.43	0.38	0.27	0.26	0.31	0.33	0.40	0.30	0.44	0.31	0.35	0.08	0.35	0.05
Pied Avocet	0.00	0.03	0.03	0.18	0.18	0.25	0.17	0.08	0.01	0.10	0.12	0.02	0.14	0.09	0.05	0.05
Black-necked Grebe	0.15	0.18	0.17	0.32	0.07	0.05	0.00	0.02	0.06	0.05	0.10	0.06	0.13	0.11	0.07	0.04
Cape Shoveler	0.15	0.27	0.14	0.17	0.26	0.19	0.22	0.14	0.21	0.22	0.14	0.09	0.21	0.05	0.16	0.05
Yellow-billed Duck	0.00	0.04	0.04	0.06	0.13	0.13	0.19	0.14	0.10	0.06	0.01	0.01	0.10	0.06	0.05	0.06
Lesser Flamingo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.13	0.03	0.00	0.00	0.00	0.05	0.05
Additional species	0.15	0.32	0.32	0.56	0.85	0.81	0.71	0.53	0.25	0.30	0.21	0.14	0.60	0.24	0.26	0.14
Total	**0.81**	**1.28**	**1.12**	**1.68**	**1.76**	**1.70**	**1.60**	**1.32**	**1.11**	**1.15**	**1.04**	**0.62**	**1.52**	**0.26**	**1.01**	**0.25**
De Hoop Vlei																
Cape Shoveler	1.06	2.45	1.86	2.34	1.79	1.88	1.27	1.09	1.34	1.18	1.34	1.34	1.93	0.42	1.23	0.13
Great Crested Grebe	0.61	0.64	0.52	0.42	0.64	0.68	0.61	0.48	0.55	0.43	0.39	0.59	0.59	0.10	0.51	0.09
White-breasted Cormorant	0.94	0.43	0.39	0.42	0.42	0.69	0.55	0.41	0.73	0.64	0.75	0.78	0.48	0.12	0.71	0.18
Yellow-billed Duck	0.19	0.19	0.21	0.26	0.63	1.08	0.77	0.64	0.66	0.49	0.38	0.27	0.52	0.36	0.44	0.19
Black-necked Grebe	0.27	0.42	0.75	0.67	0.11	0.18	0.11	0.42	0.88	0.60	0.21	0.27	0.37	0.29	0.44	0.25
Caspian Tern	0.76	0.12	0.11	0.21	0.32	1.08	0.26	0.43	0.13	0.19	0.41	0.87	0.35	0.37	0.46	0.30
Black-winged Stilt	0.30	0.56	0.32	0.40	0.35	0.31	0.25	0.17	0.26	0.28	0.32	0.51	0.36	0.11	0.31	0.11
Greater Flamingo	0.19	0.28	0.35	0.31	0.12	0.01	0.02	0.03	0.02	0.05	0.04	0.19	0.18	0.15	0.09	0.08
Southern Pochard	0.30	0.34	0.56	0.50	0.17	0.03	0.00	0.00	0.00	0.00	0.07	0.21	0.27	0.24	0.10	0.13
Great White Pelican	0.05	0.01	0.04	0.08	0.16	0.35	0.25	0.12	0.14	0.25	0.09	0.06	0.15	0.13	0.12	0.07
Whiskered Tern	0.00	0.00	0.07	0.01	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.25	0.00	0.00
Red-knobbed Coot	0.26	0.27	0.29	0.30	0.24	0.19	0.19	0.18	0.25	0.24	0.32	0.36	0.25	0.05	0.27	0.06
Maccoa Duck	0.36	0.06	0.01	0.04	0.02	0.01	0.01	0.04	0.05	0.01	0.03	0.00	0.03	0.02	0.08	0.14
Pied Avocet	0.10	0.15	0.07	0.10	0.11	0.11	0.19	0.04	0.07	0.16	0.11	0.12	0.12	0.04	0.10	0.04
Crowned Cormorant	0.02	0.01	0.00	0.02	0.02	0.05	0.10	0.00	0.04	0.00	0.00	0.01	0.03	0.04	0.01	0.02
Additional species	0.47	0.60	0.44	0.61	0.88	0.95	0.99	0.74	0.72	0.58	0.70	0.62	0.75	0.22	0.64	0.10
Total	**5.87**	**6.52**	**5.99**	**6.68**	**6.61**	**7.59**	**5.55**	**4.78**	**5.84**	**5.11**	**5.16**	**6.20**	**6.49**	**0.69**	**5.50**	**0.55**
Bot River Estuary																
Caspian Tern	0.29	0.32	0.18	0.45	1.87	1.98	2.67	1.05	0.32	0.48	0.48	0.55	1.24	1.05	0.53	0.28
Great Crested Grebe	0.82	1.10	1.66	1.61	0.93	0.76	1.19	0.87	0.54	0.47	0.95	0.56	1.21	0.36	0.70	0.20
White-breasted Cormorant	0.36	0.32	0.36	0.36	0.58	0.79	0.54	0.75	0.83	0.55	1.04	0.39	0.49	0.18	0.65	0.27
Hartlaub's Gull	0.90	0.67	0.46	0.80	1.05	0.96	0.26	0.12	0.32	0.43	0.61	0.29	0.70	0.30	0.44	0.28
Greater Flamingo	0.68	0.84	0.59	0.96	0.67	0.27	0.29	0.06	0.42	0.00	0.16	0.18	0.60	0.28	0.25	0.25
Cape Shoveler	0.50	0.17	0.09	0.08	0.32	0.40	0.80	0.19	0.23	0.50	0.32	0.33	0.31	0.27	0.34	0.13
Swift Tern	0.11	0.04	0.13	0.57	0.17	0.80	0.18	0.23	0.82	0.06	0.08	0.09	0.31	0.30	0.23	0.29
Yellow-billed Duck	0.19	0.14	0.08	0.16	0.37	0.45	0.61	0.57	0.40	0.27	0.20	0.19	0.30	0.21	0.30	0.15
Red-knobbed Coot	0.24	0.30	0.20	0.13	0.11	0.12	0.11	0.28	0.06	0.38	0.36	0.49	0.16	0.08	0.30	0.15
Black-necked Grebe	0.20	0.05	0.06	0.17	0.03	0.04	0.05	0.00	0.09	0.02	0.39	0.17	0.07	0.05	0.14	0.14
Kelp Gull	0.32	0.36	0.13	0.13	0.40	0.34	0.25	0.29	0.41	0.12	0.27	0.15	0.27	0.12	0.26	0.11
Great White Pelican	0.10	0.30	0.07	0.03	0.06	0.23	0.34	0.15	0.10	0.05	0.30	0.00	0.17	0.14	0.12	0.10
Black-winged Stilt	0.07	0.22	0.18	0.18	0.26	0.23	0.17	0.09	0.13	0.08	0.12	0.06	0.21	0.03	0.09	0.03
Sandwich Tern	0.00	0.00	0.33	0.01	0.03	0.06	0.03	0.01	0.00	0.00	0.00	0.00	0.08	0.13	0.00	0.00
White-fronted Plover	0.06	0.06	0.08	0.05	0.09	0.12	0.09	0.11	0.12	0.03	0.25	0.13	0.08	0.03	0.12	0.07
African Black Oystercatcher	0.15	0.03	0.09	0.06	0.08	0.15	0.11	0.08	0.16	0.11	0.13	0.10	0.09	0.04	0.12	0.03
Additional species	0.63	0.49	0.56	0.37	0.43	0.68	0.73	0.54	0.45	0.49	0.72	0.55	0.54	0.14	0.56	0.10
Total	**5.62**	**5.41**	**5.24**	**6.13**	**7.44**	**8.38**	**8.39**	**5.39**	**5.39**	**4.05**	**6.35**	**4.19**	**6.83**	**3.71**	**5.16**	**2.59**

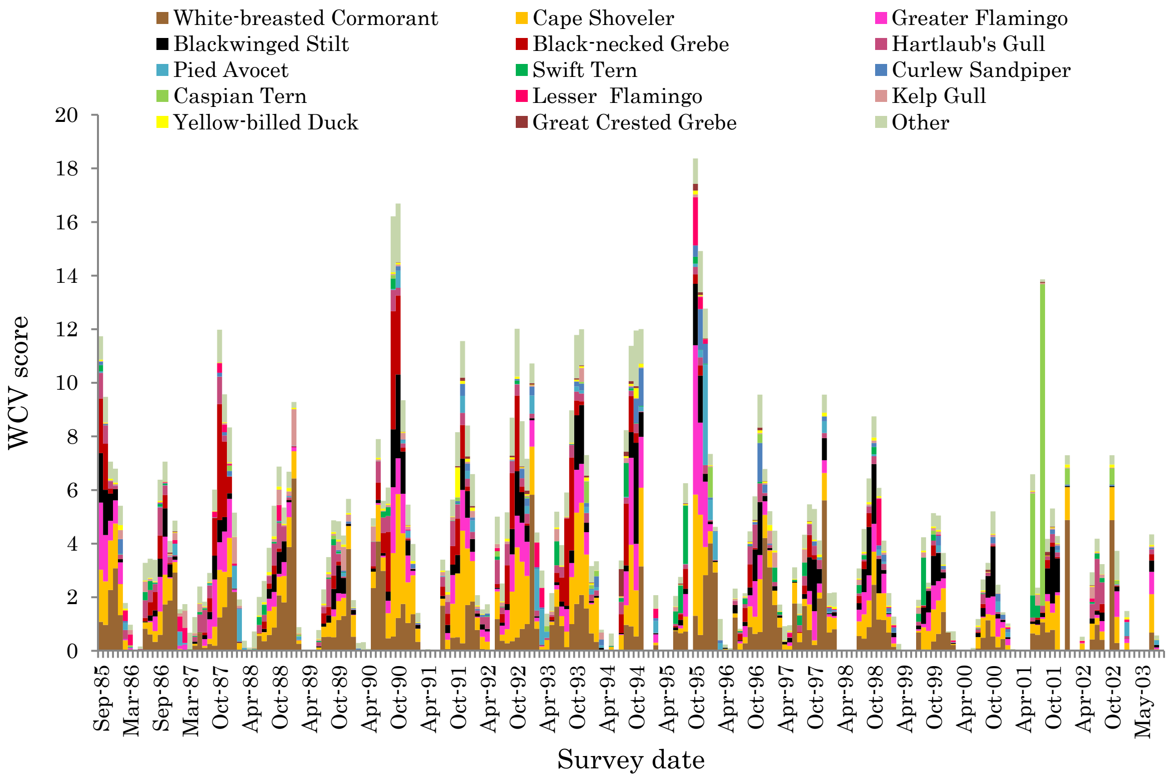


Figure 3.1 Colour-coded histogram plotting the monthly WCV scores for priority species at Rocher Pan.

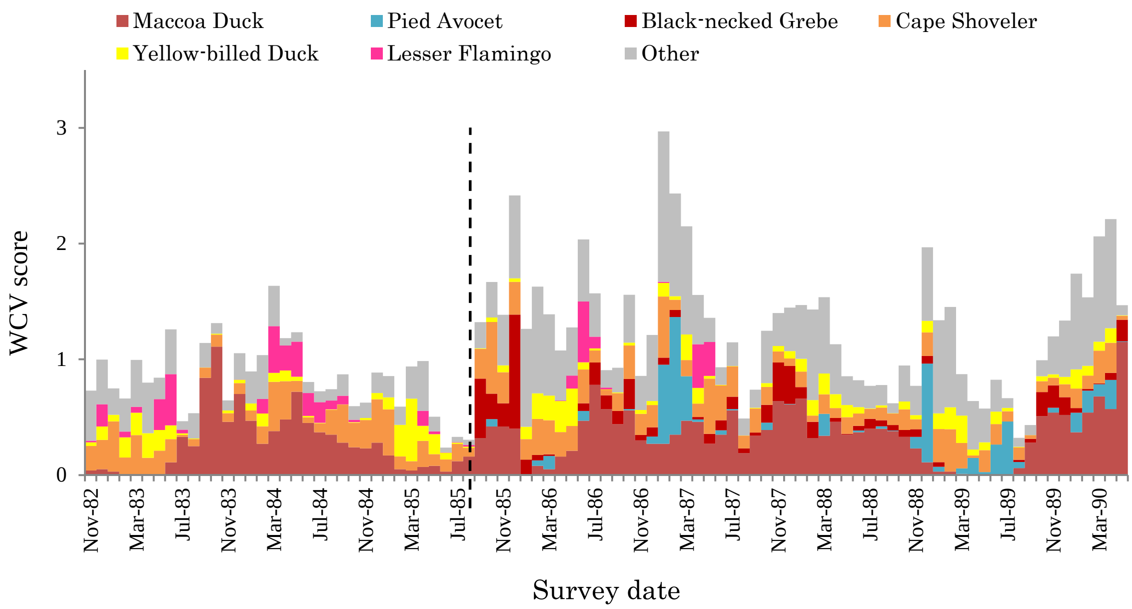


Figure 3.2 Colour-coded histogram plotting the monthly WCV scores for priority species at Droëvlei Dam. The dotted line represents the date from which all species were surveyed.

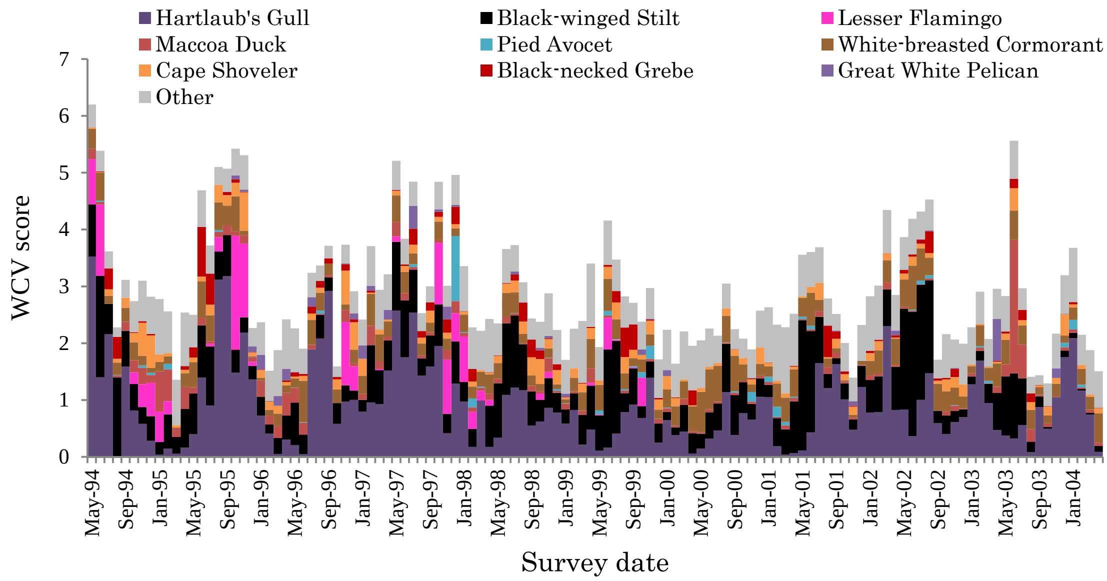


Figure 3.3 Colour-coded histogram plotting the monthly WCV scores for priority species at Paarl Waste Water Treatment Works.

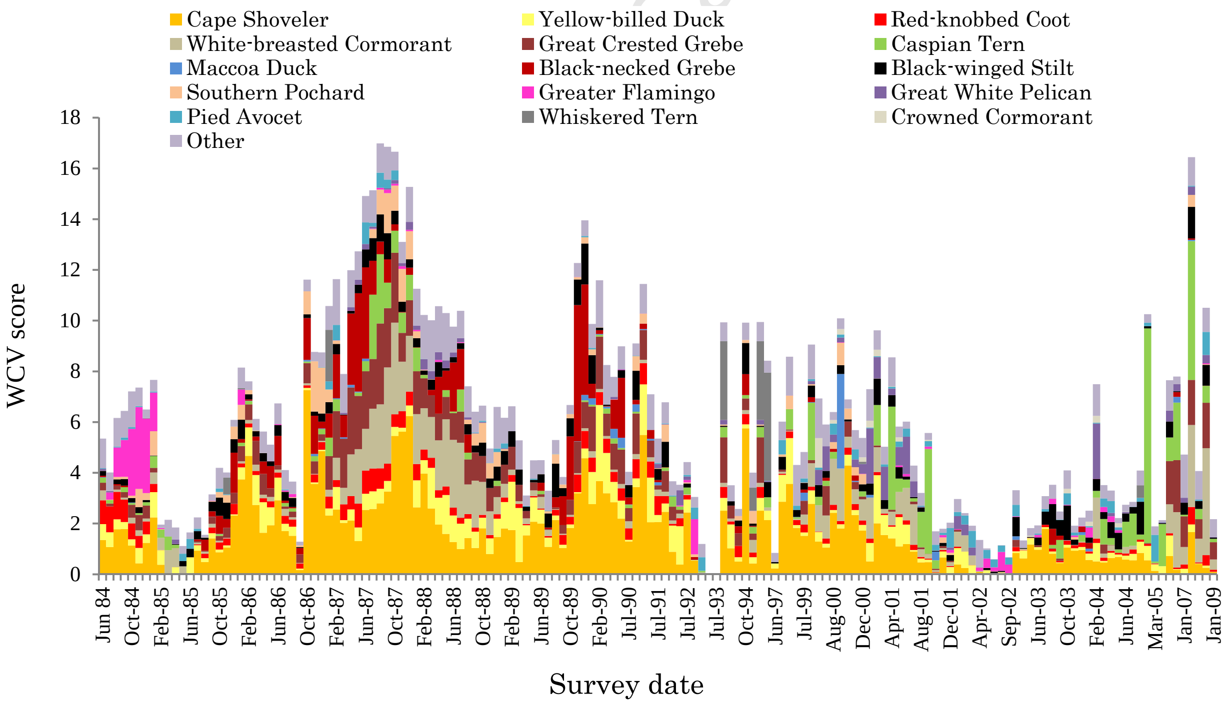


Figure 3.4 Colour-coded histogram plotting the monthly WCV scores for priority species at De Hoop Vlei.

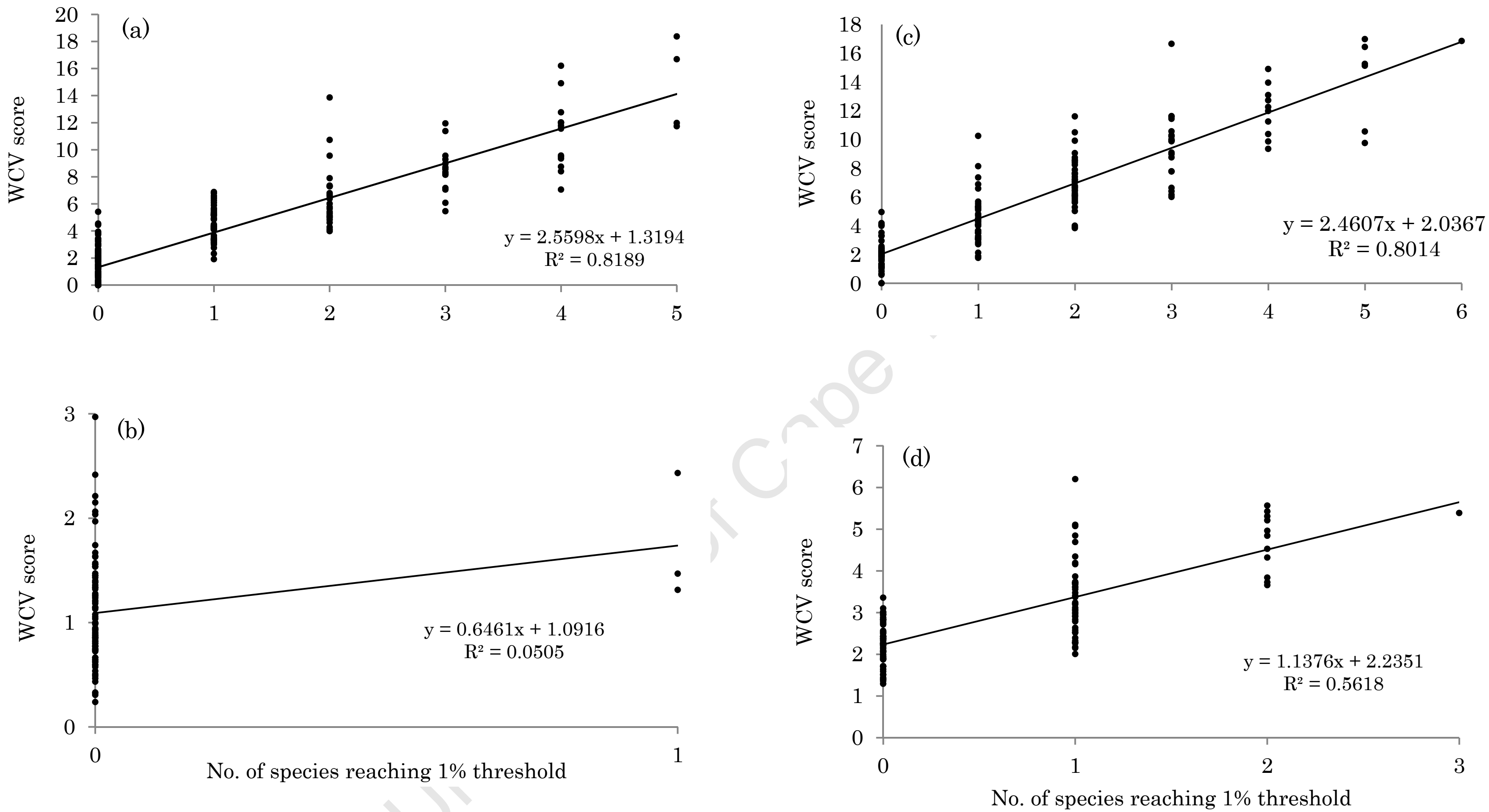


Figure 3.5 Scatterplots showing the relationship between the number of species reaching the 1% threshold and the Waterbird Conservation Value (WCV) score for (a) Rocher Pan, (b) Droëvlei Dam, (c) De Hoop Vlei and (d) Paarl Waste Water Treatment Works. Each data point represents one survey.

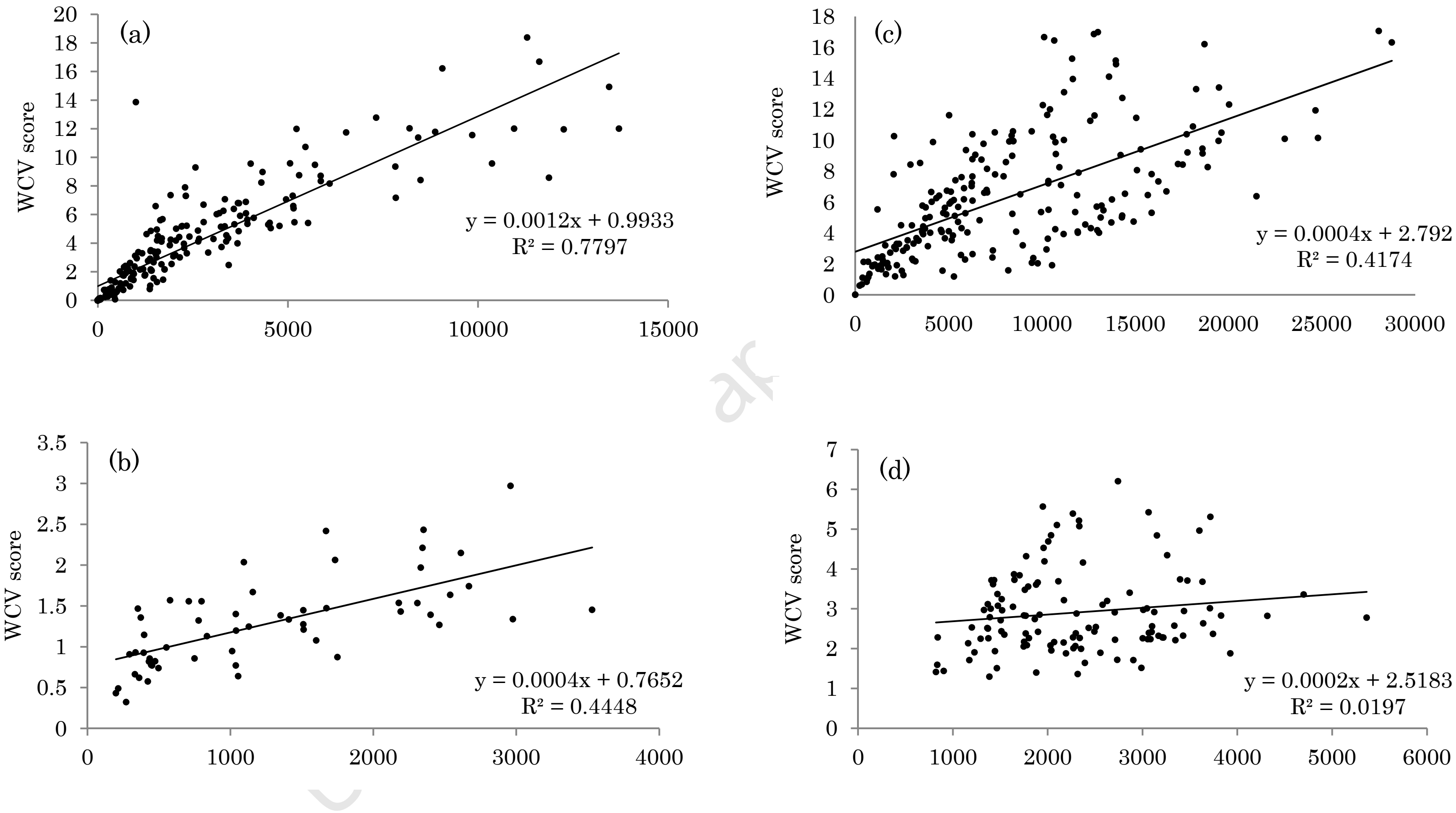


Figure 3.6 Scatterplot showing the relationship between total waterbird count (abundance) and the Waterbird Conservation Value (WCV) score for (a) Rocher Pan, (b) Droëvlei Dam, (c) De Hoop Vlei and (d) Paarl Waste Water Treatment Works. Each point represents one survey.

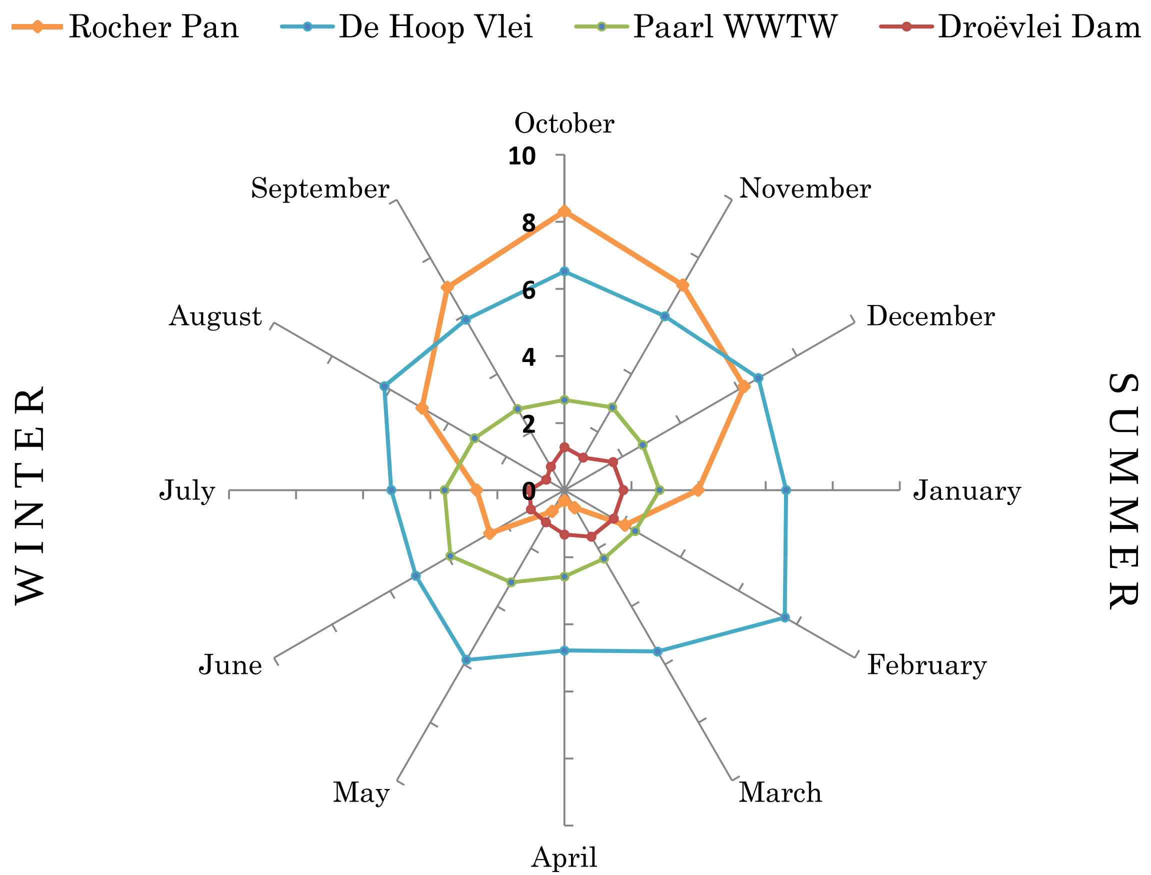
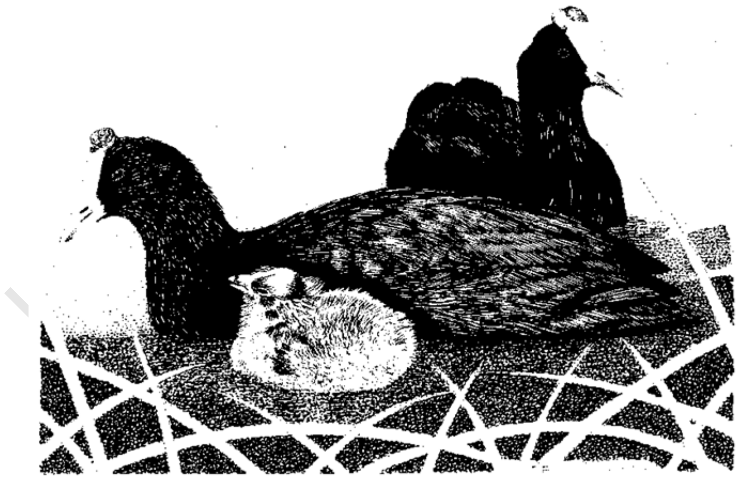


Figure 3.7 Annotated radar graphic to illustrate the change in the mean monthly Waterbird Conservation Value (WCV) scores (y-axis) for four wetland sites in the Western Cape, South Africa. The closer the lines of each site are to each other the more similar the WCV scores, the more similar their waterbird conservation value.

Chapter 4

Waterbird responses to dynamic shifts between lake and estuarine conditions at the Bot River Estuary, Western Cape, South Africa, 2002–2010: a conservation assessment



Abstract

The Bot River Estuary is a temporarily open-closed estuary on the south coast of South Africa. The mouth is artificially breached at 2–3 year intervals. I assessed the changes in waterbird composition and abundance at the estuary between 2002–2010 in relation to open-closed phases of the mouth. Three wetland conditions were identified during the study period: (1) a saline estuarine phase, (2) a brackish lagoon phase and (3) a freshwater lake phase. Sensitivity indices were calculated to measure the responses of birds between each phase and to measure overall and species trends in numbers over the eight year period. A total of 86 waterbird species were recorded; mean numbers of birds in summer was 4558 ± 2664 and 5265 ± 2759 in winter. A maximum count of 17 300 birds was recorded. Red-knobbed Coot, Common Tern and Sandwich Tern were numerically the most abundant species. Waterbirds responded variably to the changing hydrological conditions and their occurrence and dominance at the estuary is typically cyclical based on site conditions. Lake conditions supported more waterfowl, especially Red-knobbed Coot and Yellow-billed Duck, while estuarine and lagoonal phases supported more waders and shorebirds. Ramsar thresholds were met for Great Crested Grebe, White-breasted Cormorant, Caspian Tern, Greater Flamingo and Swift Tern. The estuary was designated an IBA based on large waterfowl populations; these showed declines of up to 97% over the study period, Red-knobbed Coot declined by 99%. Proposals are discussed concerning how best to manage the system to maximise waterbird abundance and conservation in light of the changing hydrological changes.

Plate 4.1 The Bot River Estuary looking eastwards from Arabella Spa and Hotel. This picture was taken one day after the mouth was artificially breached in August 2003. The exposed shoreline due to the drawdown can be seen at the edge of the estuary.

Introduction

As an interface between marine and freshwater systems, estuaries are considered to be one of the most productive of aquatic eco-systems (Breen and McKenzie 2001). The transition zones created between freshwater input at the head of the estuary and saltwater entry at the estuary mouth, contribute to high levels of biodiversity within these systems (Whitfield and Wood 2003). They are dynamic environments with conditions changing more widely, rapidly and frequently than any other aquatic habitat. This is due primarily to changes in river inflow and tidal exchange when the mouth is open to the sea. Fluctuations in salinity, nutrient content, sediment deposition and water-levels are considered to be some of the important features that contribute to changes in biodiversity and ecological processes within these systems (Whitfield 2001). Estuarine biota constitutes both freshwater and marine taxa which adapt to the physical and chemical components associated with changes in the system (Whitfield and Wood 2003). Waterbirds are among the most conspicuous of all organisms in aquatic systems and, as the top predator, their abundance and occurrence often reflects the health of these systems. This allows for rapid assessment of the ecological state within wetlands and aquatic systems (Peakall and Boyd 1987, Martinez et al. 2005).

In South Africa more than 75% of all estuaries are temporarily closed to the sea with openings occurring naturally (i.e. during flooding events) or artificially (i.e. during mechanical breaching of the sand-barrier) (Whitfield 1992, Whitfield et al. 2008). These 'change-over' periods are usually of short duration but rapidly alter estuarine conditions. The effects on birds of such abrupt abiotic events are difficult to assess because these events are generally unpredictable, and while it is usually easier to monitor the post-event condition, the context of pre-event conditions is generally lacking.

The Bot River Estuary, known locally as the Botriviervlei, is subject to regular artificial breaching of its mouth (van Niekerk et al. 2005). For the most part it exists as a coastal lake or lagoon with periodic estuarine (tidal) interludes. Water flow has been reduced or diverted through human interference which has impacted on the natural ability of the estuary to breach regularly. Estuarine ecologists are in favour of breaching the estuary annually in order to restore the estuary to its original reference state and maintain it as an open estuarine system (van Niekerk et al. 2005). In contrast, other users (birdwatchers, fisherman and residents) support a less frequent breaching protocol in order to support recreational activities and aesthetic aspects at the estuary (Bally and Branch 1986).

Monthly waterbird surveys were carried out in the early 1980s (Heÿl and Currie 1985) and preliminary results showed that the estuary provided a safe dry-season refuge for many waterbird species, particularly waterfowl and that changes in the hydrology did impact on the waterbird community. Surveys were re-instated in the early 1990s (Coordinated Waterbird Counts, Animal Demography Unit; Taylor et al. 1999) and were carried out twice-yearly during the austral mid-summer and mid-winter periods. However, much of these data have been collected over short-term periods or at intervals that are too coarse to determine the short- or long-term impact of breaches on the waterbird community at the estuary. Consequently, this has led to insufficient data on which to base an effective waterbird conservation strategy for the estuary.

From February 2003, more regular surveys were introduced to provide opportunities to document and monitor the impacts of impending changing hydrological conditions on the waterbird community. These surveys continued, albeit at varying intensity, over the next six years covering four breaches. The draft management plan for the estuary (Anon. 2001) focuses primarily on overall management policies for the catchment and the estuary itself, particularly in light of the controlled artificial breaching policy. No sound waterbird conservation strategy is included in the management plan.

In this chapter, I investigate how waterbirds respond to changing hydrological and chemical conditions at the Bot River Estuary and compare these results with those obtained by Heÿl and Currie (1985). Application of the Waterbird Conservation Value (WCV) score is applied locally in the context of the estuary's hydrological cycle to assess conservation value of waterbirds in light of the changing physical conditions. I highlight the overall conservation importance of the site for waterbirds and discuss recommendations for maintaining and conserving waterbird diversity in light of current management policies at the estuary.

Study area

The Bot River Estuary (34°21'S 19°06'E) is the second largest estuary in the Western Cape covering an area of *c.* 14 km^2 when fully inundated (Branch et al. 1985). The estuary is fed by the Bot River from the north and the small Afdaks River which enters the estuary halfway along the eastern shore (Figure 4.1). The catchment (c. 900 km^2) is split into three sections: the Bot, Swart and Afdaks Rivers; the confluence of the Swart and Bot Rivers is c. 10 km from the head of the estuary (Figure 4.1) and comprises 45% land under agriculture, 43% natural fynbos vegetation, 4.5% covered by alien vegetation (including plantations) and the remaining 7.5% urban settlements, road infrastructure and other modified landscapes (Adams 2000). Agriculture results in high loads of silt and other erosion inputs into the system (Koop et al. 1983). The surrounding geology comprises predominantly shales, and Table Mountain Sandstone occurs in the Afdaks River catchment. Unlike most rivers in the Western Cape, water entering the estuary is generally unstained by humic acids resulting in good light penetration (Koop et al. 1983).

The estuary is located within the Overberg wheatbelt within the Cape Floristic Region, a global biodiversity hotspot, and an Important Bird Area (Barnes 1998, Cowling et al. 2003). The estuary is also part of the Kogelberg Biosphere Reserve, and is itself an Important Bird Area, on account of its waterbird populations (Barnes 1998). It was rated by Turpie (1995) as one of the top 10 estuaries in South Africa for waterbirds.

The hydrodynamics of the estuary were described by Branch et al. (1985), van Niekerk and Huizenga (2000) and van Niekerk et al. (2005). The estuary opens periodically to the sea, on a scale of years, either naturally after heavy flooding or by artificially breaking the sandbar, a process known as breaching (Koop et al. 1983, van Niekerk et al. 2005). Although some wave-overtopping of the sandbar by seawater occurs during spring high tides, the lack of regular marine input into the estuary for periods of a year or more has a substantial impact on the biodiversity and functioning of the system. Due to limited and reduced salinities in the system the estuary mostly functions as a coastal freshwater lake rather than a typical tidal estuary (Koop et al. 1983). During the study period, the estuary was breached four times; three were artificial and one was natural. The estuary has only opened naturally on four occasions between 1940 and 2010 (Bally 1985, van Niekerk et al. 2005, this study).

The estuary is shallow (averaging 1.5 m below MSL) with a narrow central area up to 2.5 m below MSL (Koop 1982, van Niekerk et al. 2005). Water-levels fluctuate between 1.4 m and 2.7 m above MSL when the mouth is closed, but varies seasonally and from year to year (Branch et al. 1985).

The estuary comprises five major habitats for waterbirds: (a) open water which supports two submerged plants: *Ruppia maritima* generally dominates throughout the estuary but at depths less than 1.9 m above MSL, while smaller *Potamogeton pectinatus* beds occur in the northern sections; (b) a rocky, eastern shoreline with limited or no emergent vegetation; (c) extensive *Phragmites* and *Scirpus* areas in the north where the Bot River enters and near the mouth of the Kleinmond estuary, and smaller stands where the Afdaks River enters the estuary; (d) an open, vegetated western shoreline comprising mainly of marsh grass *Chondropetalum tectorum* and salt marsh grass *Sarcocornia natalensis* and (e) a sandy beach near the mouth with dune vegetation (Koop et al. 1983, Adams 2000). A few emergent rocks occur in the open water of the northern sections of the estuary and these become exposed when water-levels are low.

Methods

I used data from waterbird surveys conducted between 2002 and 2010 (Coordinated Waterbird Counts, Animal Demography Unit). Most surveys were conducted at monthly intervals from February 2003 to December 2006 and at quarterly or six-monthly intervals from December 2006 to February 2010. Surveys were conducted in six sections with each being covered by a team of 3–4 people. Surveys started at 0800 and took about four hours.

I assessed changes in abundance, composition (richness) and biomass of waterbird species before, during and after a breaching event. These periods corresponded with three phases of the estuary: the lake phase, the estuary phase and lagoon phase respectively, with the phases characterized by mouth status, salinity and water-level (Table 4.1). Apart from the abrupt transition between the lake phase and the estuary phase, these other transitions were gradual.

Species were categorized as residents or Palearctic migrants and grouped into three feeding guilds (Appendix 1.3, Chapter 1): herbivores, piscivores and invertebrate feeders. Species that occurred on 25% or more of the surveys and that averaged 10 or more individuals were selected for analyses. These focal species made the greatest contribution to the waterbird population at the estuary.

By tracking the changes in mean abundance of the focal species through the phases, I evaluated (a) which species responded first to the changing conditions, (b) how the changing conditions impacted on them, (c) whether changes in abundance were linked to water-level and/or salinity changes and (d) the length of time it took for waterbird numbers to recover after a breach. I calculated a sensitivity index for each species; the index was designed to measure the changes in numbers immediately before and after a breaching event. For example, to calculate the sensitivity index (SI) for a species from the lake phase to the estuarine phase and I calculated the difference between mean abundance values in the estuarine phase and the immediately preceding lake phase, and divided this by the mean of these two values. In general, for all pairs of phases, this is represented by the formula:

$$SI = \frac{x_i - x_{i-1}}{\frac{1}{2}(x_i + x_{i-1})}$$

where

x_i = mean abundance of the species for phase i,

x_{i-1} = mean abundance of the species for the preceding phase i–1.

Negative values for this index indicate a decline in numbers after a breach; positive values indicated increases.

To relate changing hydrological conditions during each phase to changes in waterbird abundance and composition, I examined four hydrological variables: water-level, salinity, run-off and rainfall. Water-level data were obtained from a recorder (GR4003) located at the Ysterklip Jetty (Figure 4.1), maintained by the Department of Water Affairs and Forestry and were corrected to MSL (mean sea-level) by subtracting 0.6 m. Salinity data were provided by CapeNature (S. Gildenhuys *in litt.*). Data were incomplete and only available for 29 of the 55 months; missing monthly data were linearly interpolated from the values on either side of the missing month(s). Monthly run-off into the estuary was measured at river gauging station G4H014-A01 situated on the farm Roode Heuvel (34°14'S, 19°12'E) in the Bot River c. 13 km upstream of the head of the estuary, maintained by the Department of Water Affairs and Forestry. Rainfall data were supplied by the South African Weather Service for the weather station 00062235 at Haasvlakte (34°13'S, 19°08'E) situated within the catchment area of the Bot River. Summer and winter are defined as October–March and April–September for residents and as September–April and May–August for migrants, respectively.

Correspondence Analysis (CA) was used to assess the relationship between species abundance and the eleven estuarine phases. Correspondence analysis was selected because it would determine the association between waterbird composition and the hydrological conditions associated with each estuarine phases (the data matrix) and display these in graphical two dimensional plots (Greenacre 1984). The interpretation of these plots is based on the clusterings of the two "clouds" of points representing the rows (species) and columns (wetland state) of the data matrix and in understanding why they are clustered (Underhill & Peisach 1985). In the plots generated by the correspondence analysis, a cluster of row points plotted close together represent sites which have a similar species composition and a cluster of column points plotted close together represent species which have a similar pattern of occurrence across the sites. When plotted, each plot represents the first principal plane of the correspondence analysis, and contains the maximal amount of information from the data basis, in relation to a set of criteria described by Greenacre (1984). The correspondence analysis was carried out using function CA of the package SensoMineR in program R v. 2.15.0 (R Development Core Team 2012), and was performed using a mean species count and estuary phase matrix. The results were then plotted using graphical functions in program R.

I then examined which hydrological variable (see above) could best explain the variability in the waterbird composition during the different estuarine phases. Linear models were fitted to the row scores (wetland states) of the first CA dimension. Akaike's An Information Criterion (AIC) (Sakamoto et al. 1986) was used to determine the goodness of fit of the models based on the explanatory variables used.

To assess the waterbird conservation value and assign conservation importance during the estuary's hydrological changes, I calculated WCV scores per month and per estuarine phase for all species; scores were computed and interpretations made based on methods outlined in Chapter 2. Colour-coded histograms and radar plots were used to graphically display the results.

I make reference to six-monthly surveys from July 1993 to June 2002 (Harebottle and Delport 2000) as needed, particularly when these data show comparative results during a breaching event. However, interpretation of the six-monthly surveys should be viewed with caution because the time between surveys is too broad to give clear indications of trends or patterns for the entire population or individual species. Nevertheless, certain conclusions can be drawn and these are made using results from the present study and previous studies (e.g. Heÿl and Currie 1985).

Results

Physio-chemical conditions

During the study period, the Bot River Estuary shifted through 11 phases (Table 4.2, Figure 4.2). During the initial lake phase (February 2002–August 2003), the water-level in the estuary averaged 2.53 above MSL with a maximum of 2.88 above MSL in July 2002. Salinity values in July and August 2003 averaged 7.1 p.p.t., an essentially freshwater system. The sand barrier was breached in August 2003 which opened the mouth and the estuary became inter-tidal. Water-levels had dropped by 1.66 m to 1.12 m above MSL and salinity increased five-fold to 30.7 p.p.t. indicating the commencement of the estuary phase. By December 2003 salinity levels had gradually increased to 38.2 p.p.t. After the mouth closed in January 2004, water-levels decreased and reached 0.85 m above MSL in May 2004 (Figure 4.2). At the end of the lagoon phase in March 2005, one year after the closure of the mouth, water levels had increased to 1.6 m above MSL. The winter rains resulted in salinity decreasing to 19.8 p.p.t. in October 2004 and after the dry season, it increased to 26.1 p.p.t. in March 2005.

The start of the 2005 winter rains in April 2005 heralded the beginning of the second lake phase (Figure 4.2) with water-levels rising to 3.2 m above MSL in June 2005, the highest recorded during the study period. Levels averaged 2.5 m above MSL during this phase and by June 2006 had dropped to 1.9 m above MSL; levels had increased to 2.2 m above MSL two months later in August 2006. Salinity dropped to

7.2 p.p.t. in April 2005 and averaged 8.8 p.p.t. for the rest of this phase. The second estuarine phase started in late August 2006 after the estuary was artificially breached; water-levels dropped to 1.1 m above MSL and salinity increased to 15.8 p.p.t. in September 2006. The mouth closed in October 2006; salinity increased to 19.4 p.p.t. During the subsequent lagoon phase, water-levels averaged 1.1 m above MSL but ranged from 0.8 m above MSL in February 2007 to 2.2 m above MSL in July 2007. Salinities ranged from 26.5 p.p.t. in February 2007 to 15.7 p.p.t. in July 2007 and averaged 25.3 p.p.t. Water-levels during the third lake phase averaged 2.4 m MSL while salinity averaged 7.4 p.p.t. The third mouth opening during the study period resulted in water-levels dropping to 0.9 m above MSL in November 2008 from a level of 2.3 m above MSL in July 2008. The estuary's salinity rose from 7.4 p.p.t. to 28.5 p.p.t. during the same period. The lagoon phase that followed until the end of the study period showed little variability in salinity and water-level values (Table 4.2).

Rainfall and run-off

Most rain, on average, fell from June–August (> 80 mm/month) with a peak in July; the driest months were from December–March (< 30 mm/month) (Figure 4.3a). The months with the highest mean winter and lowest summer rainfall were July (104 mm) and January (17 mm) respectively.

There were inter-annual fluctuations in seasonal rainfall (Figure 4.3b). The wettest winters occurred in 2005 (632 mm) and 2006 (602 mm); 2004 (336 mm) and 2003 (381 mm) were the driest. The wettest summers were 2006/07 (369 mm), 2007/08 (322 mm) and 2003/04 (320 mm); other summers had more than 300 mm of rainfall. The driest summers were 2004/05 (120 mm) and 2008/09 (134 mm).

The inflow rate was correlated to rainfall ($r = 0.79$, $p < 0.001$). Mean winter flow rates from 2002–2005 were considerably lower than those from 2006–2010 (Figure 4.4). The highest mean flow rate was recorded in November 2008 (8.2 m^3/sec.) and the lowest during January 2004 (0.024 m^3/sec.). The highest maximum flow rate of 212 m^3/sec was recorded during November 2008 when 200 mm was recorded in a flood event. The 620 mm of rain recorded during the five-month period ending November 2008 resulted in a large flow-rates into the estuary which raised water-levels and which led to decision to breach the estuary artificially already in September 2008.

Waterbird composition, abundance and seasonality

A total of 55 waterbird surveys was carried out at the Bot River Estuary between February 2002 and February 2010 and 86 species of waterbirds were recorded. Of these, 66 were residents and 20 were Palearctic migrants. Twenty-three species (27%) were recorded on fewer than 25% of surveys or in small numbers (Table 4.3). Of the focal 63 species, 38 contributed more than 95% of the total abundance of waterbirds at the wetland; of these 33 were residents and five were Palearctic migrants (Table 4.3).

Overall, waterbird abundance ranged from 1 095 birds (May 2005) to 17 290 (August 2003) (Figure 4.5). Mean summer abundance was 4 559 ± 2 664 and winter abundance 5 266 ± 2 759 (Table 4.3). Large fluctuations in abundance occurred throughout the study period and were associated with changes in hydrological conditions (Figure 4.5). Red-knobbed Coot was the dominant species and accounted, on average, for 35% of all waterbirds in summer and 57% in winter (Table 4.3). Fluctuations in abundance were less pronounced when the Red-knobbed Coot was excluded from the analysis highlighting the species' dominance at the estuary, particularly under lake conditions (Figure 4.5). August had the highest mean count of 6 493 waterbirds and May the lowest count of 3 075. During the study period, peak counts of for species (Greater Flamingo, Common Tern, Sandwich Tern and Yellow-billed Duck) exceeded 2 000 birds on one occasion; Red-knobbed Coot exceeded this level during 19 surveys.

There was no clear overall seasonal pattern for waterbirds; migratory shorebirds and terns revealed usual austral summer seasonal occurrence and generally started arriving in November and departed by April (Figure 4.6). Some species from the resident waterbird community showed seasonal patterns of occurrence. Of the waterfowl, Egyptian Goose, Yellow-billed Duck, Spur-winged Goose, Southern Pochard and Great Crested Grebe showed the strongest seasonal patterns; all except Southern Pochard showed high abundance during summer, the pochard occurred mainly during winter and early summer (Figure 4.7). Greater Flamingo numbers were, on average, larger in summer (September–January). Black-winged Stilt numbers showed notable increases in summer (October–February); Kittlitz's Plover numbers were higher from December to February with an exaggerated March peak (Figure 4.8).

Other species that reveled seasonality included Reed Cormorant and African Darter; their numbers were, on average, higher in late winter (July–September); in contrast White-breasted Cormorant was more abundant in late summer and early winter (February– May) (Figure 4.8). Caspian Tern showed strong late summer peaks at the estuary from January to March (Figure 4.8). For Palearctic shorebirds, numbers of Little Stint peaked in March and Curlew Sandpiper in January. Both species started to arrive in small numbers from September–November. Most Little Stints had arrived by December, while Curlew Sandpipers showed their major influx in January (Figure 4.8).

Curlew Sandpiper populations departed abruptly in April. Small numbers of Little Stint were still present in April; all birds had departed by May (Figure 4.8).

Changes in abundance and composition during different phases

General changes and patterns

Total waterbird numbers varied at the estuary and fluctuated widely between the different phases (Table 4.4) over the study period; there was a general pattern of decreases in overall abundance after breaches occurred (i.e. estuarine phases) when the system was open to the sea followed by increases during the lagoon and lake phases when the system was closed to the sea (Figure 4.9).

Prior to the August 2003 breach, during the first lake phase, the mean abundance was 10 593 waterbirds. Numbers then declined by 24%, to 8 109 birds, during the first estuarine phase (after the mouth was opened) and during the first lagoon phase decreased, on average, by a further 41% to 2 664 birds. The second lake phase saw a 75% increase in numbers (4 865 birds) which was followed by a 40% decrease, to 3 012 birds, after the second mouth opening in August 2006 and then a 30% increase, to 3 880 birds, during the next lagoon phase. Numbers continued to increase during the third lake phase and averaged 6 961 birds. This was followed by a 30% decline during the third estuarine phase when the mouth was breached in September 2008, and a further 11% decline by the time the next lagoon phase ended; numbers by the end of the latter phase averaged 2 696 birds. Natural breaching of the sandbar in July 2009 occurred before the lagoonal state could shift into a more freshwater lake phase; mean waterbird numbers declined again by a further 30%, to 1 877 birds during the fourth estuarine phase. After the mouth closed in December 2009 to the end of the study period in February 2010 mean waterbird numbers increased by 61%, to 2 785 birds, from the estuarine phase.

Phase by phase breakdown

Table 4.4 and Figures 4.9, 4.10 and 4.11 show the changes in species and species group abundance during each of the eleven phases of the estuary for the study period. Prior to the August 2003 breach (i.e. the first lake phase), waterfowl dominated the waterbird community and comprised 87.8% of all birds at the estuary; of this Red-knobbed Coot comprised 72.4% and was the most abundant species at the estuary during this phase (Figure 4.10). Following the breaching event, and during the first estuarine phase, Red-knobbed Coot declined, on average, by 41%. Numbers of resident shorebirds and resident gulls tended to increase when the mouth was tidal and showed increases of 24% and 65%

respectively. Flamingos were also abundant during this phase with numbers showing an eight-fold increase over the first lake phase.

After closure of the mouth, Red-knobbed Coot numbers continued to decline during the first lagoon phase; a further 95% reduction was noted. Large declines were also reported in populations of Red-Billed Teal (76%), Cape Shoveler (42%), Great Crested Grebe (38%), Little Grebe (77%), Greater Flamingo (68%) and Hartlaub's Gull (43%) during this phase. Interestingly, Yellow-billed Duck and Spur-winged Goose numbers showed an increase of 54% and 130% respectively. White-breasted Cormorant and Kittlitz's Plover showed, on average, a two-fold increase, in numbers. During the second lake phase Red-knobbed Coot populations recovered and showed an 11-fold increase; other waterfowl that showed increases were Egyptian Goose (156%), Yellow-billed Duck (77%), Cape Shoveler (145%) and Little Grebe (520%). Great Crested Grebe numbers declined by 62% during this phase. Greater Flamingos continued to decline and numbers decreased by a further 89% in the second lake phase. Kittlitz's Plover numbers declined by 52% at the site during this phase.

During the second mouth opening from August–October 2006, Red-knobbed Coot (28.8%) dominated but showed a 65% decline in numbers from the previous lake phase. Hartlaub's and Kelp Gull numbers increased by 148% and 53% respectively and comprised 9.6% and 9.1% of the overall waterbird community at the estuary. Other species that showed considerable increases included Great White Pelican (285%), Little Egret (165%), African Sacred Ibis (102%), African Darter (80%), Blacksmith Lapwing (44%) and Kittlitz's Plover (33%). Although Yellow-billed Duck, Egyptian Goose, Reed Cormorant and Cape Shoveler numbers declined during this period they still comprised the dominant group of species at the estuary; combined they constituted 22.2% of all waterbirds.

Red-knobbed Coot numbers declined by a further 34% in the second lagoon phase and although they dominated the waterbird community comprised 15% of all waterbirds at the estuary (Table 4.4). Greater Flamingo was the next dominant species and comprised 11.9% of all waterbirds and showed an almost 500-fold increase from the previous phase. Cape Cormorant was absent from all previous phases as an abundant species but comprised 3.4% of the total waterbird population during this phase. Notable declines in numbers were noted for African Darter (72%), Cape Shoveler (54%) and Egyptian Goose (35%), and numbers of Hartlaub's and Kelp Gulls showed decreases of 11% and 39% respectively. In contrast, a range of species showed significant increases including African Spoonbill (818%), White-fronted Plover (631%), Black-winged Stilt

(227%), Three-banded Plover (191%), White-breasted Cormorant (105%), Black-necked Grebe (58%) and Great Crested Grebe (63%).

During the third lake phase, Red-knobbed Coot and Yellow-billed Duck comprised half of all waterbirds present; they constituted 39.8% and 10.2% respectively. Reed Cormorant and Common Tern were the next most abundant species and comprised 6.6% and 5.5% respectively. Numbers of three waterfowl species increased by over 300% during this phase, namely Red-knobbed Coot (375%), Yellow-billed Duck (345%) and Spur-winged Goose (314%). Cape Shoveler, Sandwich Tern and Egyptian Goose numbers increased dramatically, showing 289%, 249% and 168% increases respectively. Reed Cormorant numbers almost doubled, while Common Tern numbers increased by 60% during this phase. Species with notably declining population numbers included Greater Flamingo (92%), Little Stint (91%), African Spoonbill (72%) and Kittlitz's Plover (44%).

Three species constituted 70% of all waterbirds during the third estuarine phase: Common Tern (35.7%), Sandwich Tern (21.6%) and Red-knobbed Coot (13.6%). Other resident species that comprised substantial proportions of the waterbird community were Kelp Gull (5.8%), Hartlaub's Gull (3.9%), African Sacred Ibis (3.3%) and Reed Cormorant (2.2%). Up to 26 species showed more than 50% declines during the third breaching of the study period; Black-necked Grebe and Little Grebe showed 100% declines (Table 4.4).

The third lagoon phase comprised mainly Kelp Gull (24.2%), Reed Cormorant (20.9%) and Cape Cormorant (8.0%); these three species supported up to 53% of the waterbirds present at the estuary during this phase (Table 4.4). Red-knobbed Coot numbers declined by 81% and constituted 4.7% of all waterbirds. Egyptian Goose numbers increased by 82%; most other waterfowl did not show any large increases or declines, except for Little Grebe and Great Crested Grebe which increased in numbers (Table 4.3). Greater Flamingos disappeared from the estuary during this phase. The cormorant species and African Darter showed large (60%–438%) increases; Hartlaub's Gull showed declines of 47% and Kelp Gull numbers were 2.5 times greater than during the previous phase (Table 4.4).

There was no third lake phase as the estuary breached during the third lagoon phase before lake conditions prevailed. During the fourth estuarine phase, Kelp Gull (30.7%), Greater Flamingo (19.9%) and Hartlaub's Gull (12.5%) comprised 63% of the entire estuarine waterbird community. Red-knobbed Coot was virtually absent from the system during this phase; numbers had declined by a further 98% since the third lagoon phase. All three cormorant species showed large (> 85%) declines; additional notable declines were noted for Yellow-billed Duck, Little Grebe, Great Crested Grebe, Swift Tern, African Sacred Ibis, Little Egret and Grey Heron.

The fourth lagoon phase was the final phase of the study period and showed a more evenly distributed group of species that dominated the waterbird community; this evenness was similar to that of the other lagoon phases. Five species contributed to 60% of all waterbirds: Little Stint (19.1%), Kelp Gull (17.7%), Common Tern (11.5%), Kittlitz's Plover (8.7%) and Greater Flamingo (7.0%) (Table 4.4). Yellow-billed Duck continued to show declines, numbers dropped by a further 83%, while other species that showed significant declines included Black-winged Stilt (95%), Hartlaub's Gull (65%) and Egyptian Goose (30%). Red-knobbed Coot were low (averaging three birds). Some species showed notable increases in numbers: there were six-fold increases in African Sacred Ibis and Kittlitz's Plover populations, Reed Cormorant increased by 120%, Little Egret by 92% and Spur-winged Goose by 75%. All Palearctic migrant populations showed substantial increases except for Common Greenshank which showed a decline of 20% (Table 4.4).

Species sensitivity to changing phases

Results for the sensitivity analyses are presented here for the lake, estuarine and lagoon phases respectively, and then summarized across all phases for all species to gauge general responses for species and/or guilds.

For the lake phase, 22 species scored mean values larger or equal to zero (least sensitive) and 16 species smaller than zero (more sensitive) (Table 4.5). Red-knobbed Coot, Little Grebe, Cape Shoveler, African Darter, Yellow-billed Duck, Egyptian Goose, Cattle Egret and Reed Cormorant were the least sensitive to lake conditions; Greater Flamingo, Common Greenshank, Southern Pochard, Little Stint, Kittlitz's Plover, and African Spoonbill the most sensitive. There was some mixture of feeding guilds during this phase in how birds responded, but the data did show piscivores and herbivores showing greater preference for lake conditions compared with invertebrate feeders (Table 4.8).

When the estuary was tidal and estuarine conditions prevailed, 30 species showed a negative response to these conditions; mean indices for only seven species were positive (Table 4.6). Of these seven species, Common Greenshank, Kittlitz's Plover, and Southern Pochard responded positively to inter-tidal conditions; Little Grebe, Cape Cormorant, Black-necked Grebe, Cattle Egret, Red-knobbed Coot, Swift Tern, Hadeda Ibis, Yellow-billed Duck and Cape Shoveler showed the least preference (Table 4.6). None of the feeding guilds showed a preference for the estuarine phase.

The lagoon phase showed 26 species that, on average, responded positively to the higher water-levels and decreased salinities that occurred during this phase; 12 species showed less tolerance (Table 4.7). The species that showed greatest sensitivity were Southern Pochard, Red-knobbed Coot, African Darter, Hartlaub's Gull, Cape Shoveler and Red-billed Teal. Swift Tern, Little Stint, Black-necked Grebe, Cape Cormorant, Caspian Tern, Curlew Sandpiper and Reed Cormorant showed the greatest tolerance to these conditions. In contrast to the lake phase, piscivores and invertebrate feeders showed greater preference for lagoon conditions compared with herbivores which were mainly intolerant of conditions (Table 4.8).

In summary, species and guild responses fluctuated between the different phases (Table 4.8). Waterfowl had varying responses. Red-knobbed Coot, Cape Shoveler, Yellow-billed Duck, Red-billed Teal and Egyptian Goose all preferred the lake phases and were not able to tolerate estuarine or lagoon conditions. Cape Teal, Great Crested Grebe and Black-necked Grebe all responded with preference for lagoon conditions but not for the lake or estuarine phases. Little Grebe and Spur-winged Goose preferred lake and lagoon conditions. Southern Pochard was the only waterfowl species that tolerated estuarine conditions.

All three cormorant species preferred lake and lagoon conditions; African Darter was unable to adapt to estuarine or lagoon phases (Table 4.8). Of the waders, Cattle Egret, Hadeda Ibis and Grey Heron showed preference for the lake and lagoon phases, while Little Egret and Greater Flamingo preferred the lagoon phase. Large shorebirds such as Blacksmith Lapwing and Black-winged Stilt showed preference for lake conditions; the smaller Thee-banded Plover and White-fronted Plover preferred the lagoon phase, and Kittlitz's Plover was dominant in the estuarine phase. Hartlaub's Gull response was more positive during the estuarine phase compared to Kelp Gull which responded well to both estuarine and lagoon phases. Both Caspian and Swift Terns showed a strong preference for lagoon conditions, although Caspian Tern also showed a positive response to lake conditions. Great White Pelican showed a constant positive response during all three phases. Pied Kingfisher did not tolerate estuarine conditions.

Species in the Palearctic migrant group showed variable responses. Smaller shorebirds such as Curlew Sandpiper and Little Stint preferred the lagoon phase, the longer-legged Common Greenshank showed preference for estuarine conditions. Common Tern and Sandwich Tern, responded well to the lagoon phase although Sandwich Tern also showed strong links with the lake phase and Common Tern with the estuarine phase.

The lagoon phase supported the largest number of species (26) that showed a positive response, followed by the lake phase (20) and the estuarine phase (8) (Table 4.8). In contrast, 30 species responded negatively in the estuarine phase, 18 in the lake phase and 12 in the lagoon phase. The estuarine phase had the smallest ratio of negative to positive responses (1:0.27), followed by the lake phase (1:1.1) and the lagoon phase (1:1.7). Lake conditions thus provided a more even spread of species, while the estuarine phase showed one in every four species responding negatively and the lagoon phase one in every two species responding positively.

Waterbird and estuary phase associations

The correspondence analysis (CA) initially revealed Common Tern and Sandwich Tern as distinct outliers compared with the rest of the data points which were tightly grouped within the CA plot. This distinction resulted because of large abundance values for both species (Table 4.3). This made it difficult to interpret the underlying associations of the remaining data points. Because both species are Palearctic migrants and utilise the estuary only as a roost site (see below), and in order to elucidate the overall patterns, both terns were removed from the primary analysis and included as supplementary columns; this allowed the CA to reveal the structure hidden by the dominant effect of the two terns. The resultant plots provided a more robust output of the association between species abundance and the 11 estuarine phases.

Figures 4.12 and 4.13 show the final plots for the CA; the latter providing a detailed look at the core data points in Figure 4.12. The first axis explained 45.5% of the inertia and can be interpreted as a water-level–salinity gradient (see next section for details); phases with high water levels and low salinities are represented on the far left of the x-axis and those with low water-levels and high salinities on the far right of the x-axis. The second axis explained 21.9% of the inertia. No clear environmental component could be identified from this axis.

The plot of the first two axis of the CA (Figure 4.12) shows a strong association of 'short-legged' migratory shorebirds with the fourth lagoon phase. This phase had the lowest overall mean water-level (Table 4.2) which probably accounted for these species making use of increased shoreline and open mudflat habitats during the dry, summer months. A close-up on the central area (Figure 4.13), revealed some variation and overlap in species-estuarine relationships but some associations were noticeable: (a) a waterfowl and 'long-legged wader/shorebird' component in the top left and bottom left quadrants associated with lake phases, (b) a cormorant and 'long-legged wader' grouping in the top right quadrant which is associated with lagoon and estuarine phases of the estuary; interestingly all three gull species (Hartlaub's, Kelp and Grey-headed) were also grouped in this quadrant, (c) a predominantly 'short-legged shorebird' component was identified in the bottom right quadrant associated with saline estuarine conditions; South African Shelduck was the only waterfowl species placed in this quadrant.

Species plotted between the water-level–salinity extremes on the x-axis would generally be classified as species tolerant of either high- or low-water levels or high or low salinities and have stronger or weaker affiliations to either of these conditions depending on their location within the plot.

Modelling CA scores with hydrological variables

Seven models were considered (Table 4.9). Model selection favoured a model that considered water depth as the primary hydrological variable driving changes in the waterbird community during each of the eleven estuarine phases ($r = 0.69$, $p < 0.01$) (Figure 4.14). Model 2 was also significant, but because water depth and salinity were strongly correlated ($r^2 = 0.853$, $p < 0.0001$) and the higher AIC of Model 1, Model 2 was not considered further. None of the other five models considered were significant (Table 4.9). Similar models were fitted for the second CA axis but none of these were significant (results not shown).

In Model 1 (Figure 4.14) the lake phases were separated widely from the lagoon and estuary phases; the latter phases were more variable, and showed no clear separation but tended to reflect a single cluster. The plot showed clear separation of a high water-level/low salinity and low water-level/high salinity patterns at the estuary which are responsible for the changing waterbird composition.

Long-term trends of waterbirds to changing conditions at the estuary

Although most of the waterbird guilds showed fluctuating populations over the study period, some guilds and certain species were more badly impacted than others by the changing conditions. The waterfowl and cormorant-darter guilds showed the largest declines, populations of these guilds declined by 97% and 76% respectively between the first lake and the final lagoon phases (Table 4.8); nine out of 11 waterfowl species declined by more than 95%. Southern Pochard, Red-knobbed Coot, Little Grebe and Great Crested Grebe were the most impacted of the waterfowl species, and within the entire waterbird community; their numbers declined rapidly after the first breach in August 2003 and never recovered for the remainder of the study period. They showed the greatest intolerance to the dynamics of the estuary. Cape Teal, Red-billed Teal, Yellow-billed Duck, Cape Shoveler and Black-necked Grebe numbers showed greater fluctuations after the August 2003 breach but did occur at similar levels, at least once, before the third breach in September 2008; following this breach their numbers declined rapidly. These species were thus better able to respond to the changing conditions at the estuary between August 2003 and September 2008, and were able to tolerate the changing salinities and water-levels better than the Southern Pochard, Red-knobbed Coot, Little Grebe and Great Crested Grebe. Egyptian Goose declined by 54%.The Spur-winged Goose was the only species whose populations increased; in this case by 46%. The increase in Spur-winged Goose populations is more likely linked to increases in regional populations (Siegfried 1964, Harebottle 2003) than to conditions at the estuary. Like Egyptian Geese, Spur-winged Geese feed in the surrounding agricultural croplands and use the Bot River Estuary as a safe daytime refuge and moult site. Wheat, the predominant cereal crop in the region, is harvested in November–December (Anon. 2009) which provides the geese with harvest debris from February–March, their peak time of abundance at the estuary. The widespread availability of food and the small dams provided by agricultural activities have most likely led to the increase in Spur-winged Goose populations in the area surrounding the estuary.

Within the cormorant-darter guild, African Darter showed the largest declines (97%); Reed Cormorant had the smallest declines, at 67%. Other species that showed overall negative trends were Hartlaub's Gull, Black-winged Stilt, Blacksmith Lapwing, White-fronted Plover, Caspian Tern, African Spoonbill, Hadeda Ibis, Cattle Egret and Grey Heron (Table 4.8).

Responses of feeding guilds

Results are presented for herbivores, piscivores and invertebrate feeders. Carnivorous species were omitted because they comprised only two species (African Marsh Harrier and Black Harrier) and constituted less than 0.1% of the total biomass. The three guilds responded differently to the changing conditions at the estuary.

Herbivores constituted the smallest guild (14 species) but their numbers and associated biomass showed the greatest fluctuation between each of the phases. They were the most abundant guild during all lake phases when they dominated the waterbird community. They were most numerous during the first lake phase both in terms of abundance and biomass; here they constituted 80% of all waterbirds at the estuary and comprised 9.1-tonnes (84.5 %) of the total waterbird biomass (Figures 4.15a, b). Red-knobbed Coot comprised by far the greatest numbers within this group during the lake phases. By the end of the third lagoon phase herbivore numbers had dropped, on average, by 60% and biomass was reduced to 0.61 tonnes (Figures 4.15a, b).

The invertebrate feeders comprised the largest foraging guild with 50 species. Overall, they were the second most abundant group at the estuary over the 11 phases and showed fluctuations between phases; peak abundances coincided with either estuarine or lagoon conditions (Figure 4.15a, b), when water-levels were low. The first estuarine phase and fourth lagoon phase showed the largest numbers on average, 2 507 and 2 066 birds respectively. In terms of biomass, they contributed 4.3 tonnes (43%) to the total biomass during the first estuarine lagoon phase (Figure 4.13); in the second and third estuarine phases their contributions dropped to 0.64 tonnes and 0.63 tonnes respectively. The fourth estuarine phase recorded 1.8 tonnes of invertebrate feeders, their second largest contribution during the study period.

Less inter-phase variation was recorded for piscivores. They dominated in biomass during the second lake and third lagoon phase; numbers remained relatively stable prior to the third lake phase but showed fluctuations following the third breaching (Figure 4.15a, b). Overall, this group did not tend to show a preference for any specific phase of the estuary's open-closed cycle.

Species thresholds and Waterbird Conservation Value (WCV) scores

A total of 13 species reached global (Ramsar) population thresholds (Table 4.10) during the study period (Wetlands International 2006). Four species, Great Crested Grebe, White-breasted Cormorant, Caspian Tern and Hartlaub's Gull, passed these levels on more than 10 occasions; Great Crested Grebe recorded globally important populations on 22 surveys (40%). Eight species, Cape Shoveler, Caspian Tern, Great Crested Grebe, Greater Flamingo, Hartlaub's Gull, Swift Tern, White-breasted Cormorant, Yellow-billed Duck, occurred at levels that surpassed double the 1% threshold for southern Africa.

Seventeen species reached or surpassed sub-regional 0.5% Important Bird Area population thresholds (Table 4.10, Barnes 1998) without reaching 1% thresholds; this includes the 13 species above that reached 1% levels. The four additional species that reached these thresholds included Black-winged Stilt, Southern Pochard, White-backed Duck and White-fronted Plover (Table 4.10). Four species passed this threshold on more than 10 occasions: Great Crested Grebe, White-breasted Cormorant, Caspian Tern and Hartlaub's Gull; Caspian Tern reached sub-regional levels 14 times during the surveys (25%).

In terms of South Africa's Western Cape Province, the Bot River Estuary supported 34 species which had maximum counts representing 5% or more of the estimated provincial populations for each species; four of these species contributed more than 20%: Sandwich Tern (49.8%), Great Crested Grebe (26.6%, Southern Pochard (23.5%) and Red-knobbed Coot (20.6%) (Table 4.10).

The Waterbird Conservation Value (WCV) scores for each survey fluctuated widely (Figure 4.16). Eight surveys scored 10 or more and the survey in February 2003 exceeded 12. Generally, scores peaked in summer (October–April); May 2007 and May–June 2008 showed winter peaks. Surveys between May 2005 and November 2005 had the lowest WCV scores. The mean summer and winter scores were 6.83 and 5.16 respectively (Table 3.1).

I found that changes that contribute to the WCV score in the different phases the most interesting aspect of Figure 4.17. The lake phase had the highest mean WCV score (7.78) for each of the three phases; the lagoon (5.83) and estuary (5.22) phase had similar scores (Table 4.11). From the first lake phase to the second estuary phase there was a 45% decline in the score (from 8.37 to 4.35), and the number of species with important threshold populations dropped from eight to three. There was an increase in the composition of threshold species and the score during the following two phases and by the end of the third lake phase the WCV score had doubled to 9.60. The third estuarine phase had a 54% drop in both important species and the following three phases revealed only small changes to the overall index; similarly, threshold species did show some change during these three phases. It should be noted that the estuarine phases, except for the first estuarine phase, showed the lowest indices scores and the lake phases the highest scores.

The composition of priority species contributing to the overall WCV score described above are shown in Figures 4.18a, b. Twelve species contributed between 75–93% to the overall WCV scores in each phase; five species had scores of at least 1.0 in any one phase (Ramsar thresholds) and seven species with scores between 0.50–0.99 (Sub-regional IBA thresholds). Important species were Great Crested Grebe, White-breasted Cormorant and Caspian Tern; each had WCV scores of 1.0 or more on three occasions (Table 4.11). Figure 4.19 shows the relationship between the monthly WCV scores and the number of species reaching or surpassing the 1% threshold levels. There was a strong linear relationship ($r = 0.75$, $p < 0.01$) indicating that high indices are usually associated with more species reaching 1% thresholds; in March 2005 and February 2006 large WCV scores occurred but only two species reached the 1% thresholds. Similar relationships were obtained for the site analyses presented and described in Chapter 3.

Threatened and endemic waterbirds at the Bot River Estuary

Thirteen of the 88 waterbirds recorded at the Bot River Estuary are listed in the South African Red Data Book (Barnes 2000): three as Vulnerable (Bank Cormorant, African Marsh Harrier and Blue Crane), and nine as Near-threatened (Great White Pelican, Cape Cormorant, Crowned Cormorant, Greater Flamingo, Black Harrier, African Black Oystercatcher, Chestnut-banded Plover, Caspian Tern and Half-collared Kingfisher). Eight species are endemic to southern Africa (Hockey et al. 2005): Bank Cormorant, Cape Cormorant, Crowned Cormorant, Black Harrier, Hartlaub's Gull, African Black Oystercatcher, Blue Crane, South African Shelduck and Cape Shoveler. Of all the threatened and endemic species only the Cape Shoveler has been reported breeding at the estuary (M. Delport pers. comm.).

Discussion

Waterbird fluctuations and estuary phase associations

The results demonstrated that the shift to estuarine conditions associated with a breaching event impacted on the waterbird occurrence and abundance at the estuary. The system was subject to cyclical changes every 2–3 years, depending on the frequency of mouth breachings. Physiochemical properties and water-levels cycled through three phases: lake phase, open, tidal estuarine system phase, and lagoon phase. Each phase was characterized by varying water depths and salinities. These two environmental variables had direct impacts on the estuarine ecosystem and resulted in the waterbird community changing from one phase to the next. Water-level and salinity were thus the ultimate drivers of waterbird occurrence and abundance at the estuary; this was a primary outcome of the correspondence analysis and modeling (Figures 4.12, 4.13 and 4.14).

Waterfowl (ducks, geese, grebes and coot) were the dominant species group and had the largest influence on the overall waterbird abundance patterns observed at the estuary during the study period (Figure 4.9); influxes of large numbers of cormorants, Greater Flamingos, and migratory shorebirds and terns occurred during different phases (Figure 4.9) but these influxes of birds were sporadic and had negligible impacts on the observed overall waterbird abundance at the estuary. Due to its dominance, Red-knobbed Coot was focal in determining the changes to the overall abundance of waterbirds through each phase. When the coot was excluded from the analyses, waterbird populations fluctuated less and did not exhibit a strong overall decline (Figure 4.5).

How exactly did the hydro-dynamics at the estuary impact on waterbirds over the study period? Overall, changes in the waterbird community varied spatially and temporarily; there was a general pattern of a waterfowl-'long-legged' wader/shorebird dominated community when the lake phases occurred and a predominantly 'short-legged' shorebird/wader-dominated community when estuarine conditions existed (Figures 4.12, 4.13 and 4.14). A more cosmopolitan community occurred during the lagoon stage. The changing waterbird communities were strongly associated with the changing physio-chemical conditions in the estuary, i.e. fluctuations in water-levels and salinity, which were determined by the open-closed cycles of the mouth. These lake-estuarine cycles modified the habitats that were available to waterbirds and these habitat induced changes impacted on the way different guilds made use of the estuary.

During this study, artificial breaches usually occurred in August or September, given the hydrological conditions, this is the most likely period for them to occur (van Niekerk 2005, Anon. 2008). Coupled with falling water-levels, inter-tidal conditions alter the extent and availability of exposed shoreline and mudflats that utilized by waders and shorebirds; the Palearctic shorebirds arrive at the estuary during this period after migration. The shallow, exposed muddy and shoreline habitats, created during and after an August or September breaching event, supported more Palearctic shorebirds than when the mouth was closed and water levels were higher (Figure 4.9). This suggests that migrant shorebirds prefer these conditions and will be more abundant in years after breaches occur. For waterfowl, breaches are too short to have an immediate impact on numbers but increased salinities and turbidity (van Niekerk et al. 2005) provide unsuitable conditions for most waterfowl species, and particularly the Red-knobbed Coot.

As the estuary filled after the mouth closed, salinities dropped to below 15 p.p.t. and primary productivity increased under increasingly freshwater conditions. This led to a recurrence and dominance of waterfowl which usually occurred with the start of the winter rains in May–June in the year following a breach. Red-knobbed Coot numbers exhibited this pattern; they were almost absent until after the first mouth closure in January 2004, and by August 2004 had increased to about 800 birds. A year later, in August 2005, the number of coots increased to 1 420 and reached 7 100 birds in June 2006 shortly before the August 2006 breach. Thus, Red-knobbed Coot populations recovered steadily over a period of two years following a breach.

The degree of change to the system's physiochemical composition is strongly linked to the length of time the mouth remained opened or closed. The longest time the mouth remained open was five months, after the breach in August 2003 while the shortest was two months; mouth closure is dependent on the development of on-shore currents; these enhance the development of the sand-bar across the mouth (Branch et al. 1985). The longer the mouth remains open and the longer the connection to the sea, the greater the fish recruitment and establishment of estuarine conditions over a longer period; shorter mouth closures lead to less marine influences, poorer fish recruitment, less diverse estuarine faunal communities and a quicker return to freshwater conditions (Branch et al. 1985).

A long period of opening is advantageous for wader/shorebird communities as more open shoreline and mud-flat habitats persist for longer; in contrast, a short period allows the system to shift into to a lake phase sooner which favours the waterfowl communities particularly when coupled with long mouth closures. For example, when the estuary was closed to the sea for long periods (31 and 23 months after the 2003 and 2006 breaches respectively) waterfowl, and in particular Red-knobbed Coot, populations returned in large numbers. These 'closed' periods, which last up to three years (Branch et al. 1985), are characterised by high primary productivity, especially of aquatic macrophytes, which grow rapidly in low-salinity water and provide abundant food for the coot and other waterfowl species. If inter-breach periods are short saline conditions persist for longer and the system is unable to shift into a lake phase. This occurred between the mouth closure in February 2009 and the mouth opening in May 2009. This five-month period maintained salinities close to 30 p.p.t at the estuary; in February 2010, nine months after the May 2009 mouth opening salinity approached 35 p.p.t, almost that of seawater. Due to the estuary persisting in a high-saline condition for *c.* 16 months (September 2008 – February 2010) waterfowl and cormorant-darter populations were unable to recover while shorebird populations showed increases.

Day (1981) showed that hypersaline conditions are detrimental to estuarine primary productivity, including phytoplankton and macrophytes, the latter constituting 72% of primary production at the estuary. Zooplankton and benthic fauna are species poor with low biomass (Branch et al. 1985) and both groups generally prefer low salinity conditions. Branch et al. (1985) elucidated that the unusually low diversity of invertebrates at the estuary reflects the instability of the system. Few estuarine fish are also able to tolerate extreme saline conditions (Day 1981) and this limits their availability as suitable prey. With reduced food availability, this probably led to the large decline in the waterfowl and cormorant guilds during the fourth lagoon phase.

Feeding guild responses

Herbivores

Generally, herbivore abundance decreased after breaching events (Figures 4.15a, b). Their pattern of decline during the study period can be explained by the parallel fluctuations in the occurrence and abundance of the aquatic macrophytes, *Ruppia maritama* and *Potamogeton pectinatus*.

Red-knobbed Coot, Yellow-billed Duck, and Red-billed Teal showed preference for lake phases, with smaller numbers during lagoon and estuarine phases; however the Red-billed Teal did show a positive response after the August 2003 breach. Yellow-billed Duck and Red-billed Teal are also known to feed on invertebrates (Hockey et al. 2005), although they comprise substantially less in their diet. They were probably able to shift to this prey source during the estuarine and lagoon phases when the phytoplankton and macrophytes died back as a result of salinity increases.

For the Red-knobbed Coot, its decline was closely linked to *Ruppia* and *Potamogeton*, particularly under estuarine and lagoon conditions when salinities were high (> 25 p.p.t.); these plants do not survive in salinities above 18 p.p.t. and die-off due to desiccation and salt exposure (Adams 2000). The coot feed exclusively on these macrophytes and as they die-off it prevented them from feeding optimally. It takes about 2–3 months before complete salinity mixing occurs in the estuary after a breach, depending on the type of breach and strength of inter-tidal activity (S Gildenhhuys *in. litt.*); thus it takes a further two months before the *Ruppia* and *Potamogeton* die off and explains why a large proportion of coot remained at the estuary during the first estuarine phase; however fewer birds returned and stayed after the second and third breaches. In their study, Heÿl and Currie (1985) also found that breaches impact heavily on this species and that it can take up to 19 months before numbers show a recovery. Some birds (*c.* 20–30) were killed during the first mouth opening (September 2003) as a result of the strong outflow to the sea (Williams 2004) but this mortality probably impacts a negligible small percentage of the overall coot population at the estuary. Heÿl and Currie (1985) further state that if favourbale conditions prevail Red-knobbed Coot will remain at the estuary until there is a change in hydrological conditions. Boshoff et al. (1991b) also found a strong relationship between fluctuations in *Potamogeton* and the abundance of Red-knobbed Coot. But where do these birds go once they leave the estuary? Count data from the Klein River Estuary, 10 km to the east of the Bot River Estuary, suggested that at least Red-knobbed Coots and Cape Shoveler find refuge at this site (Harebottle 2010). I recommend that intensive ringing of coot, ducks and possibly flamingo would be a valuable exercise in determining the movements of these birds not only after a breach occurs but generally throughout their annual cycle at the estuary.

Piscivores

Contrasting patterns were shown by piscivores: African Darter, White-breasted Cormorant and Reed Cormorant. The Reed and White-breasted Cormorants both showed increasing abundance up until the third lake phase and then showed rapid declines during and after the fourth estuarine phase (Figures 4.15a, b). African Darter was less abundant and showed greater fluctuations between each phase. These species occurrence at the estuary was driven by the availability of fish, their main diet. Based on the results fish availability seemed to be impacted only after the fourth breaching event when number of these species declined. Fish recruitment is an important ecological role played by estuaries and one of the primary reasons why the Bot River Estuary is artificially breached. The estuary is one of the top three estuaries on the southern coast for marine fish recruitment; 29 fish species use the Bot River Estuary as nursery grounds (Lamberth 2000) including estuarine-dependent species such as White Steenbras *Lithognathus lithognathus*, Leervis *Lichia amia*, Cape Stumpnose *Rhabdosargus holubi* and Dusky Cob *Argyrosomus japonicus* (Lamberth and Turpie 2003). It is estimated that the estuary provides up to 20% of nursery habitat for marine and estuarine fish populations (S. Lamberth *in litt.*).

Other piscivores, such as Great Crested Grebe, Great White Pelican, Caspian Tern, Common Tern, Sandwich Tern all showed variable changes in their response to the changing conditions; only the Great Crested Grebe showed an overall decline in numbers. Overall this guild showed the least amount of variation during this study.

Critical factors determining the occurrence of piscivores at the estuary would be the availability and size of fish, and associated water turbidity during each phase. The lake phase is generally dominated by freshwater species such as Carp *Cyprinus carpio*; some estuarine species do occur, such as the endemic Bot River Klipvis *Clinus spatulatus* but they occur at lower densities due to the low salinities (< 5 p.p.t.). Carp are taken by the White-breasted Cormorant; Reed Cormorants and African Darter take small fish species. During the estuarine phase, availability of fish increases following recruitment and this probably supported and led to the increases in the numbers of cormorants, darters, and Great White Pelicans at the estuary. During the estuarine phase tidal exchanges increases water turbidity and this probably inhibits feeding by most piscivores; Great Crested Grebe, however, was more abundant during the first estuarine phase suggesting it is able to tolerate the turbid conditions. Great Crested

Grebes feed on small fish and the increase in their abundance after the breach is probably related to the recruitment of young fish into the estuary when the mouth is open. Although Great Crested Grebes are usually associated with clear waterbodies (Dean 1997), it is possible that the species preference for high visibility (Clinning 1985) is compensated for by the abundant food resources. In the Wilderness Lakes complex, Boshoff et al. (1991a) also found that abundance of Great Crested Grebes and African Darters increased during turbid conditions caused by flooding and suggested that reduced water transparency may benefit piscivores by reducing detection of the predator by the prey.

The post-breach decline of most piscivores seemed counter-intuitive, because the lowering of the water levels and increased salinities resulted in many freshwater fish being killed (Branch et al. 1985, pers. obs, A.J. Williams pers. comm.). However, these dead fish are better suited to scavengers such as Hartlaub's Gulls and Kelp Gulls, and perhaps raptors such as African Fish Eagle, than to piscivores. Also, because these species dive to catch their prey, they require relative deep water in which to feed. The water-level during the estuarine phase averaged 1.4 m above MSL and may have been too shallow for these species. These conditions may have favoured the smaller Reed Cormorant, which declined in numbers at a slower rate than the larger White-breasted Cormorant and African Darter (Table 4.2).

Invertebrate feeders

This group showed fluctuations in terms of abundance and species composition throughout the study period (Figures 4.15a, b). Based on the changing conditions, individual species responded differently but overall insectivores were the second most dominant group at the estuary both in terms of abundance and biomass.

When water levels were high, Cape Teal, Little Grebe, Black-necked Grebe, Southern Pochard and Cape Shoveler were abundant and these species dominated this group prior to a breaching event. These species were probably able to sustain their populations during periods of higher salinities (i.e. estuarine and lagoon phases), because biomass of invertebrates was higher at these times. When temporarily closed estuaries are opened to the sea, estuarine conditions are restored through increased salinities and they support a more estuarine zooplankton community, particularly when salinities and water-levels stabilise after mouth closure (Day 1981, Davies and Day 1998). These changes were probably responsible for supporting these waterfowl species through the estuarine and lagoon phases.

The Southern Pochard showed the fastest decline in this guild. This species has localised populations in the winter rainfall region; and most of the large flocks observed are known to move in from the summer rainfall region during August–September to moult (Hockey et al. 1989, 2005). Large numbers (more than 150 birds) were recorded at the estuary suggesting that these birds were most likely migrant birds and not resident birds. They prefer deep and clear freshwater systems (Hockey et al. 1989, 2005) and their decline after the first breach and virtual absence thereafter (Figure 4.10) was therefore linked to the increased turbidity and salinity associated with mouth openings and inter-tidal fluctuations. Most birds were recorded near the head of the estuary (M Delport pers. comm.) where salinities are generally low during estuarine phases (S Gildenhuys *in litt.*).

Because these species find their food amongst the submerged vegetation by either diving (grebes) or upending (shoveler) deep water and low turbidity are required for these birds to forage optimally; pre-breach conditions usually provide these conditions and explains the dominance of these species at the estuary during this period. Once inter-tidal conditions are restored during the breach phase, these species decline and are replaced by increasing numbers of waders, notably Greater Flamingo, Kittlitz's Plover and Black-winged Stilt, and gulls (Table 4.2). South African Shelduck was the only anatid to show a strong association during estuarine-lagoonal phases (Figure 4.12), confirming its affinity in tolerating high salinities than most other anatids (Hockey et al. 2005). These birds preferred shallower water and exposed muddy and sandy areas in which to feed, and their increased abundance was directly related to an increase in these types of habitats when the mouth was open. Greater Flamingos dominated the insectivores during the estuarine period which is evidenced both by their contribution to the total biomass (93%) for this group and the overall biomass (42%) for all trophic groups. With decreasing water-levels and die-off of *Ruppia* and *Potamogeton*, the insect fauna associated with the submerged vegetation became available, providing the waders improved foraging opportunities. Increases in Kittlitz's Plover, Black-winged Stilt. Curlew Sandpiper and Little Stint during the estuarine phase were probably associated with this phenomenon. A breach in late winter is therefore advantageous to these species and could make the Bot River Estuary an important site for waders under these conditions.

Water-levels decreased slowly after closure of the mouth (Figure 4.2) due mainly to high evaporation rates during the dry summer. This resulted in shoreline and other previously inter-tidal areas to remain exposed, sustaining the invertebrate abundance present in the rotting macrophytes. Kelp Gull, Greater Flamingo, White-fronted Plover, Kittlitz's Plover and Three-banded Plover increased in numbers at this time. The maximum numbers of White-fronted Plover and Kittlitz's Plover occurred in July 2004, mid-way through the austral winter; it is possible that competition with Palearctic waders during summer suppressed numbers of these resident waders during this period in spite of favourable feeding conditions created after the breach.

Overall the small resident waders respond relatively slowly to the change in hydrological conditions taking up to six months before any build of reasonable numbers, although fluctuations are evident. Palearctic species do not seem affected by changing conditions at the estuary; e.g. a count of over 900 Curlew Sandpiper in February 2000 occurred at a time when the estuary was closed and water levels were high compared with a count of just over 100 in December 2003 four months after the 2003 breach when water-levels were down and greater shoreline and mudflats were exposed.

The early lake conditions that persisted from February 2004 also resulted in unfavourable conditions for Little Grebe, Black-necked Grebe and Cape Shoveler; numbers for these species declined dramatically during this period, particularly for the grebes. All three species struggled to recover in the short- to medium term and confirm their preference for high-water levels and low-salinities, features borne out by their pre-breach abundance levels. Black-necked Grebes tend to show some tolerance, however, in the short-term (up to five months) before their numbers are seriously affected.

The drop in Greater Flamingo numbers from mid-summer to early winter could be due to adults leaving to breed at Sua Pan or Etosha Pan (Williams and Velásquez 1997) leaving behind immature and/or non-breeding adults. Both Heÿl and Currie (1985) and Boshoff et al. (1991c) found no clear seasonal pattern for Greater Flamingo during their studies of waterbirds at the Bot River Estuary and Wilderness Lakes complex respectively, although Heÿl and Currie (1985) but did find a negative correlation with water-levels.

The erratic occurrence of Pied Avocets at the estuary highlights its nomadic nature, moving in response mainly to rainfall events and changing conditions at wetland sites (Tree 1997). It is highly likely, therefore, that their occurrence at the estuary is not linked in any way to a breaching event but rather to their foraging movements over a wider area.

In summary, it was evident that numbers of birds fluctuated between phases and that abundance of different species and species groups were variably impacted. However, the decline in the total number of birds over the study period (2002–2010) was significant; this highlighted the impact of multiple breaches on the estuarine avifauna. The changes in composition and abundance of waterbirds was largely driven by the availability and abundance of different food resources; these were in turn dependent on the physio-chemical composition of the estuary during its three phases. Together with other hydrodynamic factors, they govern, to a large extent, estuarine habitats and availability of food for waterbirds, which in turn drives their diversity and abundance during different hydrological stages. Warnock and Takekawa (1995), Ntiamoa-Baidu et al. (1998), Kingsford et al. (2004) and Boertman and Riget (2005) considered water depth to be a critical environmental factor governing the availability of habitat and food for waterbirds, specifically for shorebirds and ducks. Kushlan (1986) demonstrated that for wading birds (Ciconiiformes), water levels can influence foraging tactics, breeding seasonality and colony site selection. This study has shown similar results where changing water-levels that resulted from inflow patterns and breaching events created different habitats for different waterbirds on a two-three year cycle.

Importance of the Bot River Estuary for waterbirds

During the study period, the Bot River Estuary was mainly important for waterbirds and in particular resident species, although it did have some significance for Palearctic migrants. The changing hydrological conditions determined which species and/or species groups dominated at different times. Ducks, geese and coot, which, on average comprised over half (53%) of the resident species were a prominent component of the waterbird community. Heÿl and Currie (1985) and Harebottle and Delport (2000) both found the Bot River Estuary to be an important dry-season refuge for anatidae particularly when the estuary is full and the mouth is closed (lake phase). Birds tended to move to the estuary during early parts of summer. Because ducks generally breed at temporarily inundated wetlands during winter and early summer (Heÿl et al. 1993) it is assumed that most ducks would have come from surrounding wetlands in the region; these would have started drying up at this time. However if conditions on the estuary were not favourable when they arrived, i.e. after a breach has occurred these birds must find alternative refuges. Studies at the nearby Klein River Estuary in Hermanus (25 km to the east of the Bot River Estuary) showed increased numbers of Cape Shoveler and Red-knobbed Coot in the three months following the breach at the Bot River Estuary (Harebottle 2010). Thus this estuary could provide a refuge for these two species if conditions at the Bot River Estuary are poor. Movement of other waterbirds between these two sites may also take place under similar circumstances, especially when the Klein River Estuary breaches. In the absence of other large waterbodies within 50 km of the Bot River Estuary it is assumed that waterbirds take refuge at surrounding farm dams or fly longer distances to find suitable waterbodies. However, the Bot River

Estuary is likely to be the preferred coastal refuge in the region, particularly for waterfowl. The Klein River Estuary is breached at least annually (Anon. 2010) which results in a more regular saline system than the Bot River Estuary. Prolonged macrophytic growth is therefore largely inhibited in the Klein River Estuary. As a result waterfowl numbers are lower than at the Bot River Estuary; Harebottle (2010) reported a maximum count of 589 for all waterfowl between 2001 and 2009. In contrast, the Bot River Estuary is usually breached every two-three years (Branch et al. 1985) and brackish–freshwater conditions over a prolonged period creates favourable conditions for the growth of macrophytes. As seen in this study, up to 16 000 waterfowl can utilise the Bot River Estuary; this highlights the important role the estuary plays in providing a more reliable supply of food for ducks and coot than the nearby Klein River Estuary.

The site was designated an Important Bird Area (SA118) based on the estuary meeting the 1% criterion for six species: Great Crested Grebe, Black-necked Grebe, South African Shelduck, Cape Shoveler, Southern Pochard and Red-knobbed Coot (Barnes 1998). During the study period, two species, South African Shelduck and Southern Pochard, failed to meet these thresholds. Nine additional species occurred which met the 1% criterion on more than five occasions: Caspian Tern, Greater Flamingo, Great White Pelican, Sandwich Tern, Swift Tern, Hartlaub's Gull, Kelp Gull, White-breasted Cormorant and Yellow-billed Duck. Four of these species comprised more than 15% of their estimated provincial populations and all but the Red-knobbed Coot are classified as threatened species (Barnes 2000): Great Crested Grebe, Red-knobbed Coot, Greater Flamingo and Caspian Tern. It is interesting to note the change from Barnes (1998) of a waterfowl dominated site, to one with a more cosmopolitan community (Table 4.4). The increasing instability of the system probably has resulted in this shift.

Greater Flamingo, an intra-African migrant, is probably the most significant intra-African species due to its threatened status. Birds were present all year-round, but occurred in largest numbers after a breach had occurred, and the inter-tidal conditions provided the shallow areas which the flamingos prefer when feeding (Williams and Velásquez 1997).

Conservation and management recommendations

The irregular cycles between freshwater coastal lake, tidal estuary and saline lagoon created by artificial breaching events make the Bot River Estuary difficult to manage effectively for biodiversity. At each breach an ecological equilibrium is suddenly disrupted, largely a result of the exposure and drying-out of the beds of macrophytes (Branch et al. 1985). Waterbirds play an important role in the ecological functioning of the estuary – for example, Red-knobbed Coot are estimated to utilise up to 10% of the submerged macrophytes annually (Stewart and Bally 1985). Lamont (1996) emphasized the role that Red-knobbed Coot play in maintaining wetland health; this needs to be explored further when considering the overall management of the site. Waterbirds are not the only "users" of the system; however, they are a natural component of the system, and their status should be regarded above that of other more 'ecologically-passive' users such as property owners and boat users.

Conflicts in management strategies at the Bot River Estuary have been ongoing for at least three decades (Bally 1987) and some authorities have argued that a consistent strategy will be difficult to reach due to the diversity of roleplayers and stakeholders involved (Branch et al. 1985, Bally and Branch 1986, van Niekerk et al. 2005). Nevertheless, a management strategy is necessary to avoid further conflict among users and to maintain the integrity of the system as much as possible. Branch et al. (1985) proposed that either the estuary should never be breached (allowing it to develop into a fresh-water natural lake) or that it should be breached on a controlled basis in a manner determined by certain ecological principles. For the latter, these included allowing the estuary to stabilize for three to four years before breaching and to consider breaching only when salinities fall below 6 p.p.t. the level which threatens survival of marine and estuarine dependent fish species (Bennett 1985). These points were adopted into the initial management plan and which were accepted, in 1995, by the Bot River Estuary Advisory Committee (BREAC) the main controlling body governing management policies at the estuary, established in 1993 (I. Horwood *in litt.*).

During the study period, several criteria were assessed prior to an undertaking an artificial breach (Anon. 2008). A decision to breach was taken in the first year after a breach, if water height was at or above 2.5 m above MSL and average salinity was 6 p.p.t. or less. In the second year after a previous breach, the criteria to breach were water height is at or above 2.5 m above MSL and average salinity is at or between 6–8 p.p.t., (c) if, after the third year of a previous breach, water height is at or above 2.5 m above MSL regardless of salinity or (d) by consensus of the BREAC in the event that salinities fall below 6 p.p.t. and a catastrophe is imminent (e.g. fish mortalities) regardless of water-level. It is also stipulated that any breach will take place between 1 May and 31 August and during daylight hours.

In light of the above breaching criteria, and the use of the estuary by waterbirds under varying environmental conditions (this study, Heÿl and Currie 1985), two scenarios are possible that can influence waterbird populations at the estuary: (1) should the estuary not meet the breaching criteria within three years of the previous breach, waterfowl would dominate the system and overall the estuary would support a richer waterbird community, or (2) should the estuary meet the breaching criteria within two years, the waterbird community would become shorebird-dominated. The first scenario relies on the system maintaining relatively high water-levels for a long-period allowing for good macrophytic development, which supports the estuary's regionally important waterfowl component. The second scenario causes frequent disruption to the ecological processes, creates inter-tidal areas and does not allow development and re-growth of macrophytes, making the system unfavourable to waterfowl both in the short- and long-term.

Both Heÿl and Currie (1985) and Turpie (2000) suggested that in order to maximize biodiversity and conservation importance, the Bot River Estuary should be managed as a shallow coastal lake (i.e. longer breaks between breaches) because under these conditions the estuary supports a larger diversity and abundance of waterbirds. These findings are supported in this study, which emphasizes the cyclical nature of waterbird abundance patterns at the estuary. This outcome was generally supported by the WCV scores; however, the scores also showed that the estuary supported important numbers of species during estuary and lagoonal phases (Figure 4.18a, b). Importance is therefore shifted to different species dependent on the state of the estuary.

Is it possible to maintain the Bot River Estuary as a freshwater lake rather than as a tidal estuary? Without mouth breaches, the system would undoubtedly exist more as a coastal lake rather than an open estuarine system. The diversion of water to the Kleinmond River estuary, via Die Keel (Figure 4.1) at 1.7 m above MSL, is a major factor which prevents the Bot River Estuary from opening naturally on a more regular basis. Van Niekerk et al. (2005) added that reduced run-off from the catchment, due to water abstraction from farming activities and alien vegetation infestations, has further limited the amount of inflow into the estuary; mean annual run-off has been reduced by an estimated 25.6% based on virgin run-off calculations (van Niekerk et al. 2005). Overall, the Bot River Estuary is receiving less water than it did historically and this has impacted on the hydrological regimes at the wetland. Coupled with climate change predictions of reduced and more erratic rainfall in the WRR (Midgley et al. 2005) natural breachings are less likely to occur in the future. This then favours the notion of increasing frequencies of artificial breaches to restore estuarine conditions on a more regular basis. Should this occur, and given the results in this chapter, the estuary will probably support a more shorebid-wader community. The current breaching criteria (Anon. 2009) favour a more freshwater, coastal lake system and is therefore beneficial to maintaining diverse waterbird populations (see results from this study). Lake conditions would also benefit eco-tourism and have the potential to create local employment; the training of community bird guides to showcase the birdlife of the estuary has positive socio-economic spin-offs.

However, some stakeholders do not support the view that the estuary should be maintained as a coastal freshwater lake. Van Niekerk et al. (2005) proposed that the beaching criteria be amended to favour more natural estuarine conditions. This would imply more regular breaches. More regular openings of the mouth would allow the system to function as close to its natural or reference condition; as an open system the estuary benefits from a more saline water column, an inter-tidal zone, connection to the sea and re-suspension and flushing of sediment (van Niekerk et al. 2005). The local subsistence fishermen support this more open-system as fish stocks would be replenished on a more regular basis. However, shorter intervals between breaches (as shown in this study), impacts negatively on waterbird populations at the Bot River Estuary and would not be beneficial to maintaining abundance and richness of waterbirds.

Stakeholder and user-group involvement in managing the estuary will remain a contentious and conflicting issue. The different groups expect different outcomes; van Niekerk et al. (1985) proposed a balanced approach whereby the ecological integrity of the system be prioritized ahead of satisfying the requirements of user groups. Bally (1987) and van Niekerk et al. (2005) acknowledged that the sustainability of the system can only be maintained through continued research and the open sharing of management insight. Without regular natural breaches, it is ultimately management decisions that will drive the state and condition of the estuary, and waterbirds will respond to the changes that take place. A more holistic and integrated approach is needed to managing the estuary's hydrological requirements (i.e. estuarine functioning), biodiversity and socio-economic needs.

The Bot River Estuary is an important coastal wetland for waterbirds on the south-western coastline of the winter rainfall region. The wetland is a dynamic system with an associated dynamic estuarine fauna. Its management in terms of its hydrological fluctuations impacts the long-term sustainability of waterbird populations at the site. Cyrus and Mackay (2007) demonstrated that estuarine avifaunal communities are important components in estuarine ecosystems and that the quantity and quality of water in the system is vital to maintain their diversity and abundance. Catchment management is therefore also important (van Niekerk et al. 2005) to ensure that inflow rates are not substantially reduced because this will further impact on long-term changes to the estuarine waterbird community.

This study has presented some insights in the management of the Bot River Estuary for waterbirds and provides a framework for future detailed studies and for long-term monitoring, particularly for other open-closed estuaries in the WRR and elsewhere in South Africa. In addition, more systematic and ongoing data needs to be collected on the distribution, abundance and biomass of aquatic macrophytes, benthic and zooplankton faunal communities and fish at the estuary, particularly during each of the phases described above. This will compliment and aid in the interpretation of ongoing waterbird data collection and analysis at the estuary.

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Table 4.1 The three phases of the Bot River Estuary with a description of the characteristics of each phase. Phases and descriptions have been adapted from Davies and Day (1998) and Whitfield (2003). p.p.t. = parts per thousand; MSL = mean sea level.

Phase	Mouth	Description	Water-level	Salinity
Estuary (ES)	Open	Estuary, tidal, connected to sea	Low (<0.5 m MSL)	High (>30 p.p.t.)
Lagoon (LG)	Closed	Estuary in early-closed phase following mouth closure	Mid–High (0.5–2 m MSL)	Mid–High (15–30 p.p.t.)
Lake (LK)	Closed	Estuary in late-closed phase prior to mouth opening	High (>2.0 m MSL)	Low (<10 p.p.t.)

Table 4.2 The change in phases and associated physio-chemical conditions at the Bot River Estuary from February 2002–February 2010. (A) = artificial breach, (N) = natural breach; p.p.t = parts per thousand; MSL = mean sea level.

Phase	Dates	Months elapsed	Mean salinity (p.p.t.)	Mean water-level (MSL)	Mean run-off (m^3/sec.)	No. of surveys[2]
LK 1	February 2002–25 August 2003	19	6.6	+2.5	0.7	7
ES 1 (A)	26 August 2003–15 January 2004[1]	*c.* 5	34.2	+1.1	0.4	5
LG 1	16 January 2004–March 2005	14	27.9	+1.4	0.3	13
LK 2	April 2005–17 August 2006	17	8.8	+2.5	0.9	15
ES 2 (A)	18 August 2006–29 October 2006[1]	*c.* 2	17.6	+1.2	0.8	2
LG 2	Nov 2006–June 2007	8	25.3	+1.2	1.2	3
LK 3	July 2007–28 September 2008	15	7.4	+2.6	1.5	4
ES 3 (A)	29 September 2008–4 February 2009[1]	4	28.5	+1.1	4.1	2
LG 3	5 February 2009–13 July 2009	5	23.4	+1.3	1.4	2
ES 4 (N)	14 July 2009–9 December 2009	5	25.6	+1.1	1.3	1
LG 4	10 December 2009–28 February 2010	*c.* 3	34	+0.8	0.3-	1
Total		**104**				**55**

[1] Dates represent the period from date the mouth was opened (breached) to when the mouth closed.
[2] The number of waterbird surveys that were carried out during each phase.

Table 4.3 Seasonal abundance of waterbirds at the Bot River Estuary from 2002–2010. Species marked with an asterisk (*) were recorded on less than 25% of surveys. Species sorted in descending order of mean summer abundance. Species in italics are listed in the South African Red data Book (Barnes 2000).

Species	Summer		Winter	
	Mean ± S.D.	Min-Max[1]	Mean ± S.D.	Min-Max[1]
Residents				
Waterfowl				
Red-knobbed Coot	1608.6 ± 780.1	0–12544	3018.1 ± 1467	0–15352
Yellow-billed Duck	301.6 ± 207.5	13–1423	302.2 ± 153.6	0–2030
Egyptian Goose	162.1 ± 103.3	37–845	175.4 ± 65.7	0–612
Great Crested Grebe	120.7 ± 36.1	1–356	70 ± 20.3	0–187
Cape Shoveler	108.6 ± 94.7	0–720	120.6 ± 46.4	0–466
Spur-winged Goose	61.2 ± 35.8	1–272	22.8 ± 8.7	0–156
Little Grebe	32.4 ± 24.1	0–204	121 ± 62.1	0–484
Southern Pochard	28.5 ± 44.9	0–390	20.4 ± 21.2	0–150
Red-billed Teal	19.1 ± 14.9	0–181	19.3 ± 18.8	0–130
Cape Teal	17.5 ± 8.9	0–86	6.5 ± 2.5	0–35
Black-necked Grebe	10 ± 7.9	0–103	21.5 ± 21.4	0–199
South African Shelduck*	1.1 ± 1	0–8	2 ± 2.1	0–26
Common Moorhen*	1 ± 0.7	0–9	6.4 ± 4.8	0–41
African Black Duck*	0.9 ± 0.7	0–9	0.4 ± 0.6	0–5
Maccoa Duck*	0.4 ± 0.9	0–20	0.6 ± 1	0–11
White-backed Duck*	0.4 ± 0.9	0–11	14.2 ± 11.7	0–134
Hottentot Teal*	–	–	0.1 ± 0.3	0–5
Sub-total	**2474 ± 1362.4**	**199–14182**	**3921.5 ± 1908.2**	**0–16366**
Cormorants and darter				
Reed Cormorant	128.3 ± 67.5	21–456	255.9 ± 111.4	0–947
White-breasted Cormorant	58.7 ± 21.6	10–166	78.4 ± 31.9	0–247
African Darter	21 ± 5.8	0–63	32.9 ± 18.7	0–100
Cape Cormorant	4.8 ± 4.1	0–35	40.7 ± 63.6	0–452
*Crowned Cormorant**	0.2 ± 0.3	0–2	0.5 ± 1.2	0–9
*Bank Cormorant**	–	–	0.2 ± 0.3	0–4
Sub-total	**213.1 ± 99.3**	**32–563**	**408.6 ± 227.1**	**0–1551**
Pelicans				
Great White Pelican	**34.3 ± 27**	**0–149**	**23 ± 20.5**	**0–222**
Waders				
African Sacred Ibis	30.9 ± 21.5	0–282	44.9 ± 40.6	0–199
Grey Heron	20.9 ± 9.4	1–80	19.5 ± 3.4	0–47
African Spoonbill	15 ± 5.1	0–57	18.5 ± 8.6	0–89
Little Egret	14.8 ± 5.4	1–40	21.4 ± 12.9	0–79
Hadeda Ibis	6.7 ± 2.9	0–28	17.7 ± 9.9	0–81
Cattle Egret	6.2 ± 5.4	0–48	15.1 ± 20.8	0–257
Black-headed Heron*	3.7 ± 2.3	0–16	4.7 ± 1.1	0–16
Glossy Ibis*	2.3 ± 2.0	0–20	0.1 ± 0.2	0–1
Purple Heron*	2.3 ± 1.5	0–18	1.1 ± 0.3	0–4
Water Thick-knee*	1.7 ± 1.0	0–6	2.8 ± 2.1	0–14
Yellow-billed Egret*	1.2 ± 1.2	0–10	1.6 ± 1.4	0–15
*Blue Crane**	0.9 ± 1.0	0–14	0	–
Great Egret*	0.2 ± 0.2	0–1	0.3 ± 0.3	0–3
Hamerkop*	0.1 ± 0.3	0–1	0.3 ± 0.5	0–5
*Black Stork**	–	0–1	–	–
African Jacana*	–	–	0.1 ± 0.2	0–1
Black-crowned Night-heron*	–	–	0.2 ± 0.1	0–1
Sub-total	**107 ± 59.3**	**37–314**	**148.3 ± 102.4**	**0–376**
Flamingos				
Greater Flamingo	**457.2 ± 212.5**	**0–2884**	**188.9 ± 193.4**	**0–1619**

Table 4.3 contd

Species	Summer		Winter	
	Mean ± S.D.	Min-Max¹	Mean ± S.D.	Min-Max¹
Shorebirds				
Kittlitz's Plover	94.5 ± 38.7	18–241	51.2 ± 17.7	0–207
Black-winged Stilt	47.5 ± 7.7	1–124	21.2 ± 6.6	0–125
Blacksmith Lapwing	46.4 ± 14.4	3–96	43.9 ± 9.6	0–102
White-fronted Plover	14.3 ± 4.7	0–59	20.8 ± 13.3	0–106
Three-banded Plover	13.1 ± 5.9	0–35	13.1 ± 4.1	0–56
African Snipe	4.8 ± 2.2	0–21	6.7 ± 1.9	0–25
Pied Avocet*	1.9 ± 2.1	0–35	1.0 ± 1.8	0–27
African Black Oystercatcher	0.3 ± 0.5	0–12	0.1 ± 0.2	0–2
_Chestnut-banded Plover_*	–	–	0.1 ± 0.2	0–2
Sub-total	**222.8 ± 76.3**	**92–458**	**158 ± 55.4**	**0–371**
Gulls				
Hartlaub's Gull	209.7 ± 90.8	27–728	133.2 ± 82.7	0–434
Kelp Gull	188.3 ± 82.7	56–577	181 ± 78.2	0–867
Grey-headed Gull*	1.4 ± 1.2	0–7	1.3 ± 1.5	0–12
Sub-total	**399.4 ± 174.7**	**128–845**	**315.5 ± 162.4**	**0–912**
Terns				
Swift Tern	62.8 ± 60.2	0–704	46.3 ± 58.6	0–511
Caspian Tern	18.7 ± 15.8	0–88	7.9 ± 4.1	0–44
Sub-total	**81.4 ± 76**	**0–739**	**54.2 ± 62.8**	**0–515**
Kingfishers				
Pied Kingfisher	9.5 ± 4	1–28	12.1 ± 2.6	0–29
Giant Kingfisher*	0.5 ± 0.5	0–4	1.1 ± 0.3	0–4
Malachite Kingfisher*	0.3 ± 0.3	0–2	0.7 ± 0.4	0–4
_Half-collared Kingfisher_*	0	–	0.1	0–1
Sub-total	**10.3 ± 4.8**	**1–30**	**14 ± 3.5**	**0–31**
Rallids				
African Purple Swamphen*	0.3 ± 0.4	0–4	0.9 ± 0.5	0–5
Black Crake*	0.1 ± 0.1	0–1	0.2 ± 0.4	0–3
Sub-total	**0.4 ± 0.5**	**0–4**	**1.1 ± 0.9**	**0–5**
Raptors				
African Fish-Eagle*	6.2 ± 1.8	1–23	4 ± 1	0–11
_African Marsh-Harrier_*	1.9 ± 0.6	0–5	1.8 ± 0.8	0–8
_Black Harrier_*	0.1 ± 0.2	0–2	0.3 ± 0.4	0–2
Sub-total	**8.2 ± 2.5**	**1–25**	**6.1 ± 2.2**	**0–14**
Paleractic migrants				
Shorebirds				
Little Stint	75.5 ± 64.5	0–554	0.5 ± 1.0	0–8
Curlew Sandpiper	33.1 ± 36.4	0–263	0.6 ± 0.8	0–11
Common Ringed Plover*	15.6 ± 9.1	0–72	1.2 ± 1.2	0–9
Common Sandpiper*	7.1 ± 10.1	0–66	0.3 ± 0.6	0–5
Common Whimbrel*	5.8 ± 5.1	0–34	–	–
Sanderling*	3.9 ± 5.4	0–64	–	–
Ruff*	1.8 ± 3.2	0–30	–	–
Common Greenshank	0.7 ± 0.7	0–12	0.3 ± 0.3	0–4
Eurasian Curlew*	0.6 ± 0.9	0–8	0.1	0–1
Red Knot*	0.5 ± 1.0	0–11	–	–
Marsh Sandpiper*	0.5 ± 1.0	0–9	–	–
Grey Plover*	0.4 ± 0.7	0–11	–	–
Terek Sandpiper*	0.1 ± 0.4	0–4	–	–
Wood Sandpiper*	0.1 ± 0.2	0–2	–	–
Ruddy Turnstone*	0.1	0–1	0.1	0–1
Sub-total	**145.5 ± 138.6**	**0–767**	**3.0 ± 4.1**	**0–14**

Table 4.3 contd

Species	Summer		Winter	
	Mean ± S.D.	Min-Max[1]	Mean ± S.D.	Min-Max[1]
Terns				
Common Tern	296.6 ± 226.2	0–2351	21.6 ± 15	0–211
Sandwich Tern	99.7 ± 190.1	0–2059	1.4 ± 1.3	0–13
White-winged Tern*	6.8 ± 9.1	0–90	0.3 ± 0.5	0–5
Little Tern*	0.1	0–1	–	–
Sub-total	**403.1 ± 425.4**	**0–4501**	**23.3 ± 16.8**	**0–229**
Raptors				
Osprey*	**0.7 ± 0.4**	**0–4**	**0.2 ± 0.2**	**0–3**
Waders				
White Stork*	**1.5 ± 4.2**	**0–107**	**–**	**–**
Sub-total: Residents	**4008 ± 2095.4**	**1237–16497**	**5239.1 ± 2738.6**	**0–17282**
Sub-total: Palearctic migrants	**550.8 ± 568.7**	**48–4436**	**26.4 ± 21.2**	**0–936**
Overall total	**4558.9 ± 2664.1**	**1344–16600**	**5265.6 ± 2759.8**	**0–17290**

[1] The sub-total values here reflect the minimum/ maximum number for the group profile as a whole and not the sum of individual minima/maxima for each species which would represent estimated min./max. carrying capacity and not actual min./max. numbers reflected by the dataset

Table 4.4 Change in the mean abundance of 39 species of waterbirds during 11 hydrological phases at the Bot River Estuary from February 2002–February 2010. For estuarine phase abbreviations refer to Table 4.2.

Species	Estuary phase											% overall change
	LK1	ES1	LG1	LK2	ES2	LG2	LK3	ES3	LG3	ES4	LG4	
Residents												
Waterfowl												
Red-knobbed Coot	7670.9	4428.8	230.1	2556.1	889.0	583.3	2771.8	650.5	125.5	2.0	3.0	-99.9%
Egyptian Goose	210.4	135.6	95.1	243.9	153.0	99.0	265.8	87.5	159.0	167.0	122.0	-42.0%
Red-billed Teal	38.0	53.2	12.7	10.8	23.0	34.5	41.3	3.0	1.5	0.0	0.0	-100.0%
Southern Pochard	56.9	172.2	2.0	0.3	9.0	0.0	0.0	3.0	1.5	0.0	0.0	-100.0%
Spur-winged Goose	39.7	25.0	57.5	41.0	32.0	26.3	108.8	30.5	14.5	33.0	58.0	46.4%
Yellow-billed Duck	591.0	145.0	223.2	395.3	196.5	159.5	709.3	102.0	134.5	68.0	13.0	-97.8%
Cape Shoveler	239.0	100.2	57.8	141.6	116.5	52.8	205.5	13.0	25.0	6.0	1.0	-99.6%
Cape Teal	9.7	14.8	13.9	14.7	5.5	20.3	7.5	0.0	0.0	0.0	0.0	-100.0%
Black-necked Grebe	41.7	45.8	9.1	5.3	1.0	59.0	57.5	0.5	9.5	0.0	2.0	-95.2%
Great Crested Grebe	123.0	228.8	141.6	53.8	27.5	45.8	90.0	11.0	41.5	13.0	14.0	-88.6%
Little Grebe	276.1	72.0	16.2	101.9	50.0	46.0	92.0	0.0	23.5	2.0	2.0	-99.3%
Sub-total	**9296.4**	**5421.4**	**859.2**	**3564.8**	**1503.0**	**1126.3**	**4349.3**	**901.0**	**536.0**	**291.0**	**215.0**	**-97.7%**
Cormorants and darter												
African Darter	34.9	25.2	12.2	37.2	67.0	18.3	51.3	6.0	11.5	16.0	1.0	-97.1%
Cape Cormorant	17.6	0.4	9.6	21.9	23.5	137.0	158.8	12.0	217.0	13.0	3.0	-82.9%
Reed Cormorant	195.6	130.4	162.1	242.9	218.5	233.3	456.8	104.5	562.5	29.0	64.0	-67.3%
White-breasted Cormorant	114.6	27.8	46.3	79.9	70.0	143.8	184.8	76.5	122.0	18.0	16.0	-86.0%
Sub-total	**362.6**	**183.8**	**230.2**	**382.0**	**379.0**	**532.3**	**851.5**	**199.0**	**913.0**	**76.0**	**84.0**	**-76.8%**
Flamingos												
Greater Flamingo	**170.6**	**1398.2**	**447.6**	**47.1**	**1.0**	**405.8**	**30.3**	**0.0**	**37.5**	**374.0**	**194.0**	13.74%
Gulls												
Hartlaub's Gull	198.3	294.4	166.6	120.0	297.5	262.8	295.8	186.0	97.5	234.0	81.0	-59.2%
Kelp Gull	72.0	150.4	183.0	183.3	281.0	197.5	148.3	275.0	663.5	577.0	493.0	584.7%
Sub-total	**270.3**	**444.8**	**349.6**	**303.3**	**578.5**	**460.3**	**444.0**	**461.0**	**761.0**	**811.0**	**574.0**	**112.4%**
Kingfishers												
Pied Kingfisher	**13.0**	**6.2**	**7.9**	**14.1**	**11.5**	**18.3**	**19.3**	**8.0**	**15.5**	**14.0**	**13.0**	0%
Pelicans												
Great White Pelican	**5.9**	**10.2**	**18.7**	**26.6**	**102.5**	**87.8**	**117.0**	**19.5**	**34.0**	**120.0**	**110.0**	1778.0%
Shorebirds												
Blacksmith Lapwing	50.1	44.8	44.1	45.2	65.0	54.0	62.3	27.5	45.0	32.0	3.0	-94.0%
Black-winged Stilt	30.1	37.2	30.1	36.2	22.0	72.0	70.3	28.5	15.0	19.0	1.0	-96.7%
Kittlitz's Plover	10.1	53.4	121.0	57.7	76.5	154.3	85.8	71.0	3.5	42.0	241.0	2276.0%
Three-banded Plover	10.1	9.0	14.8	17.1	8.5	24.8	11.5	4.0	1.0	1.0	35.0	245.0%
White-fronted Plover	22.4	6.6	29.8	18.6	5.5	40.3	35.3	32.5	0.5	2.0	2.0	-91.0%
Sub-total	**123.0**	**151.0**	**239.8**	**174.9**	**177.5**	**345.3**	**265.0**	**163.5**	**65.0**	**96.0**	**282.0**	129.3%
Terns												
Caspian Tern	16.4	5.8	16.2	18.7	4.0	9.8	12.5	6.0	9.5	4.0	12.0	-26.9%
Swift Tern	68.7	10.2	26.8	28.2	32.5	250.8	239.3	49.5	124.5	0.0	135.0	96.5%
Sub-total	**85.1**	**16.0**	**43.0**	**46.9**	**36.5**	**260.5**	**251.8**	**55.5**	**134.0**	**4.0**	**147.0**	72.6%
Waders												
African Sacred Ibis	10.3	52.2	29.1	30.9	62.5	80.8	41.0	155.5	96.0	14.0	78.0	658.3%
African Spoonbill	6.6	14.2	22.5	20.7	9.5	87.3	24.0	8.0	6.5	7.0	0.0	-100.0%
Cattle Egret	48.0	7.8	6.8	7.6	0.0	1.0	8.0	2.0	3.0	2.0	0.0	-100.0%
Hadeda Ibis	13.3	4.6	8.3	20.3	7.0	21.3	23.3	3.0	28.5	8.0	3.0	-77.4%
Little Egret	12.7	27.4	13.7	16.1	41.5	40.3	29.3	7.5	38.0	13.0	25.0	96.6%
Grey Heron	29.1	13.2	13.4	25.7	36.5	33.8	43.0	11.5	17.5	5.0	8.0	-72.5%
Sub-total	**120.0**	**119.4**	**93.8**	**121.3**	**157.0**	**264.3**	**168.5**	**187.5**	**189.5**	**49.0**	**114.0**	-5.0%
Palearctic migrants												
Shorebirds												
Common Greenshank	5.3	20.2	15.8	3.9	12.0	29.8	2.0	13.5	0.0	28.0	22.0	316.2%
Curlew Sandpiper	4.4	41.0	51.2	9.9	2.0	1.8	22.3	0.0	0.0	0.0	102.0	2203.2%
Little Stint	2.6	43.4	66.8	60.4	18.0	93.5	8.0	0.0	0.0	0.0	531.0	20550.0%
Sub-total	**12.3**	**104.6**	**133.7**	**74.3**	**32.0**	**125.0**	**32.3**	**13.5**	**0.0**	**28.0**	**655.0**	**5231.4%**
Terns												
Common Tern	51.3	205.4	215.5	99.9	33.5	241.0	386.0	1712.5	10.5	14.0	321.0	525.91%
Sandwich Tern	82.6	48.0	25.2	10.0	0.0	13.5	46.3	1034.5	0.0	0.0	76.0	-7.9%
Sub-total	**133.9**	**253.4**	**240.6**	**109.9**	**33.5**	**254.5**	**432.3**	**2747.0**	**10.5**	**14.0**	**397.0**	**196.5%**
Sub-total: Residents	10446.9	7751	2289.8	4681.0	2946.5	3500.9	6496.7	1995	2685.5	1835.0	1733.0	-83.4%
Sub total: Palearctic migrants	146.2	358.0	374.3	184.2	65.5	379.5	464.6	2760.5	10.5	42.0	1052.0	620.0%
Overall total	10593.1	8109.0	2664.1	4865.2	3012.0	3880.4	6961.3	4755.5	2696.0	1877.0	2785.0	-73.7%

Table 4.5 Sensitivity indices for 38 waterbird species during two lake phases of the Bot River Estuary from 2002–2010. Species sorted in descending order of sensitivity based on mean values of the index. H = Herbivore, I – Invertebrate feeder, P = Piscivore. For response + denotes a positive response, – denotes a negative response, and 0 unknown.

Species	Feeding guild	Lake phase		Mean	Response
		1	2		
Greater Flamingo	I	-1.62	-1.72	-1.67	– –
Common Greenshank	I	-1.20	-1.75	-1.47	– –
Southern Pochard	H	-1.43	–	-1.43	– 0
Little Stint	I	-0.10	-1.68	-0.89	– –
Kittlitz's Plover	I	-0.71	-0.57	-0.64	– –
African Spoonbill	I	-0.08	-1.14	-0.61	– –
Cape Teal	I	0.06	-0.92	-0.43	+ –
White-fronted Plover	I	-0.46	-0.13	-0.30	– –
African Sacred Ibis	I	0.06	-0.65	-0.30	+ –
Three-banded Plover	I	0.15	-0.73	-0.29	+ –
Black-necked Grebe	I	-0.52	-0.03	-0.27	– –
Kelp Gull	I	0.00	-0.28	-0.14	+ –
Common Tern	P	-0.73	0.46	-0.14	– +
Great Crested Grebe	P	-0.90	0.65	-0.12	– +
Hartlaub's Gull	I	-0.33	0.12	-0.10	– +
Little Egret	I	0.16	-0.32	-0.08	+ –
Swift Tern	P	0.05	-0.05	0.00	+ –
Red-billed Teal	H	-0.16	0.18	0.01	– +
Black-winged Stilt	I	0.18	-0.02	0.08	+ –
Blacksmith Lapwing	I	0.03	0.14	0.08	+ +
Sandwich Tern	P	-0.86	1.10	0.12	– +
Curlew Sandpiper	I	-1.35	1.71	0.18	– +
Caspian Tern	P	0.14	0.25	0.20	+ +
Pied Kingfisher	P	0.56	0.05	0.31	+ +
Great White Pelican	P	0.35	0.29	0.32	+ +
White-breasted Cormorant	P	0.53	0.25	0.39	+ +
Grey Heron	P	0.63	0.24	0.44	+ +
Spur-winged Goose	H	-0.33	1.22	0.44	– +
Hadeda Ibis	I	0.84	0.09	0.46	+ +
Cape Cormorant	P	0.78	0.15	0.46	+ +
Reed Cormorant	P	0.40	0.65	0.52	+ +
Cattle Egret	I	0.12	1.56	0.84	+ +
Egyptian Goose	H	0.88	0.91	0.90	+ +
Yellow-billed Duck	H	0.56	1.27	0.91	+ +
African Darter	P	1.01	0.95	0.98	+ +
Cape Shoveler	I	0.84	1.18	1.01	+ +
Little Grebe	I	1.45	0.67	1.06	+ +
Red-knobbed Coot	H	1.67	1.30	1.49	+ +

Table 4.6 Sensitivity indices for 38 waterbird species during four estuarine phases of the Bot River Estuary from 2002–2010. Species sorted in descending order of sensitivity based on mean values of the index. H = Herbivore, I – Invertebrate feeder, P = Piscivore. For response + denotes a positive response, – denotes a negative response, and 0 unknown.

Species	Feeding guild	Estuarine phase				Mean	Response
		1	2	3	4		
Little Grebe	I	-1.17	-0.68	-2.00	-1.69	-1.39	– – – –
Cape Cormorant	P	-1.91	0.07	-1.72	-1.77	-1.33	– + – –
Black-necked Grebe	I	0.09	-1.37	-1.97	-2.00	-1.31	+ – – –
Cattle Egret	I	-1.44	-2.00	-1.20	-0.40	-1.26	– – – –
Red-knobbed Coot	H	-0.54	-0.97	-1.24	-1.94	-1.17	– – – –
Swift Tern	P	-1.48	0.14	-1.31	-2.00	-1.16	– + – –
Hadeda Ibis	I	-0.97	-0.97	-1.54	-1.12	-1.15	– – – –
Yellow-billed Duck	H	-1.21	-0.67	-1.50	-0.66	-1.01	– – – –
Cape Shoveler	I	-0.82	-0.19	-1.76	-1.23	-1.00	– – – –
Caspian Tern	P	-0.96	-1.29	-0.70	-0.81	-0.94	– – – –
White-breasted Cormorant	P	-1.22	-0.13	-0.83	-1.49	-0.92	– – – –
Reed Cormorant	P	-0.40	-0.11	-1.26	-1.80	-0.89	– – – –
Cape Teal	I	0.41	-0.91	-2.00	–	-0.83	+ – – 0
Grey Heron	P	-0.75	0.35	-1.16	-1.11	-0.67	– + – –
Red-billed Teal	H	0.33	0.72	-1.73	-2.00	-0.67	+ + – –
Great Crested Grebe	P	0.60	-0.65	-1.56	-1.05	-0.66	+ – – –
Curlew Sandpiper	I	1.61	-1.33	-2.00	–	-0.57	+ – – 0
Egyptian Goose	H	-0.43	-0.46	-1.01	0.05	-0.46	– – – +
Pied Kingfisher	P	-0.71	-0.21	-0.83	-0.10	-0.46	– – – –
Three-banded Plover	I	-0.12	-0.67	-0.97	0.00	-0.44	– – – +
Little Stint	I	1.78	-1.08	-2.00	–	-0.44	+ – – 0
White-fronted Plover	I	-1.09	-1.09	-0.08	1.20	-0.26	– – – +
Spur-winged Goose	H	-0.45	-0.25	-1.12	0.78	-0.26	– – – +
African Darter	P	-0.32	0.57	-1.58	0.33	-0.25	– + – +
African Spoonbill	I	0.73	-0.74	-1.00	0.07	-0.23	+ – – +
Sandwich Tern	P	-0.53	-2.00	1.83	–	-0.23	– – + 0
Black-winged Stilt	I	0.21	-0.49	-0.85	0.24	-0.22	+ – – +
Blacksmith Lapwing	I	-0.11	0.36	-0.77	-0.34	-0.22	– + – –
Greater Flamingo	I	1.57	-1.92	-2.00	1.64	-0.18	+ – – +
Little Egret	I	0.73	0.88	-1.18	-0.98	-0.14	+ + – –
Great White Pelican	P	0.54	1.18	-1.43	1.12	0.35	+ + – +
Kelp Gull	I	0.71	0.42	0.60	-0.14	0.40	+ + + –
Hartlaub's Gull	I	0.39	0.85	-0.46	0.82	0.40	+ + – +
African Sacred Ibis	I	1.34	0.68	1.17	-1.49	0.42	+ + + –
Common Tern	P	1.20	-1.00	1.26	0.29	0.44	+ – + +
Southern Pochard	H	1.01	1.86	2.00	-2.00	0.72	+ + + –
Kittlitz's Plover	I	1.36	0.28	-0.19	1.69	0.79	+ + – +
Common Greenshank	I	1.17	1.01	1.48	2.00	1.42	+ + + +

Table 4.7 Sensitivity indices for 38 waterbird species during four lagoon phases of the Bot River Estuary from 2002–2010. Species sorted in descending order of sensitivity based on mean values of the index. H = Herbivore, I – Invertebrate feeder, P = Piscivore. For response + denotes a positive response, – denotes a negative response, and 0 unknown.

Species	Feeding guild	Lagoon phase 1	2	3	4	Mean	Response
Southern Pochard	H	-1.95	-2.00	-0.67	–	-1.54	– – – 0
Red-knobbed Coot	H	-1.80	-0.42	-1.35	0.40	-0.79	– – – +
African Darter	P	-0.70	-1.14	0.63	-1.76	-0.74	– – + –
Hartlaub's Gull	I	-0.55	-0.12	-0.62	-0.97	-0.57	– – – –
Cape Shoveler	I	-0.54	-0.75	0.63	-1.43	-0.52	– – + –
Red-billed Teal	H	-1.23	0.40	-0.67	–	-0.50	– + – 0
Common Greenshank	I	-0.25	0.85	-2.00	-0.24	-0.41	– + – –
Black-winged Stilt	I	-0.21	1.06	-0.62	-1.80	-0.39	– + – –
Blacksmith Lapwing	I	-0.02	-0.18	0.48	-1.66	-0.34	– – + –
Yellow-billed Duck	H	0.42	-0.21	0.27	-1.36	-0.22	+ – + –
Egyptian Goose	H	-0.35	-0.43	0.58	-0.31	-0.13	– – + –
African Spoonbill	I	0.45	1.61	-0.21	-2.00	-0.04	+ + – –
Cattle Egret	I	-0.14	2.00	0.40	-2.00	0.06	– + + –
Spur-winged Goose	H	0.79	-0.20	-0.71	0.55	0.11	+ – – +
Kelp Gull	I	0.20	-0.35	0.83	-0.16	0.13	+ – + –
African Sacred Ibis	I	-0.57	0.25	-0.47	1.39	0.15	– + – +
Little Grebe	I	-1.26	-0.08	2.00	0.00	0.16	– – + +
Grey Heron	P	0.01	-0.08	0.41	0.46	0.20	+ – + +
White-fronted Plover	I	1.28	1.52	-1.94	0.00	0.21	+ + – +
Great White Pelican	P	0.59	-0.16	0.54	-0.09	0.22	+ – + –
Kittlitz's Plover	I	0.78	0.67	-1.81	1.41	0.26	+ + – +
Pied Kingfisher	P	0.24	0.45	0.64	-0.07	0.32	+ + + –
Great Crested Grebe	P	-0.47	0.50	1.16	0.07	0.32	– + + +
Little Egret	I	-0.67	-0.03	1.34	0.63	0.32	– – + +
Sandwich Tern	P	-0.62	2.00	-2.00	2.00	0.34	– + – +
Common Tern	P	0.05	1.51	-1.98	1.83	0.35	+ + – +
White-breasted Cormorant	P	0.50	0.69	0.46	-0.12	0.38	+ + + –
Three-banded Plover	I	0.49	0.98	-1.20	1.89	0.54	+ + – +
Cape Teal	I	-0.06	1.15	–	–	0.54	– + 0 0
Hadeda Ibis	I	0.57	1.01	1.62	-0.91	0.57	+ + + –
Greater Flamingo	I	-1.03	1.99	2.00	-0.63	0.58	– + + –
Reed Cormorant	P	0.22	0.07	1.37	0.75	0.60	+ + + +
Curlew Sandpiper	I	0.22	-0.13	–	2.00	0.70	+ – 0 +
Caspian Tern	P	0.94	0.84	0.45	1.00	0.81	+ + + +
Cape Cormorant	P	1.84	1.41	1.79	-1.25	0.95	+ + + –
Black-necked Grebe	I	-1.34	1.93	1.80	2.00	1.10	– + + +
Little Stint	I	0.42	1.35	–	2.00	1.26	+ + 0 +
Swift Tern	P	0.90	1.54	0.86	2.00	1.33	+ + + +

Table 4.8 Summary of sensitivity indices across all 11 phases of the Bot River Estuary from 2002–2010. The response notation indicated if a species responded strongly positive (++, values > 0.5), weakly positive (+, values < 0.5 but > 0), strongly negative (– –, values < –0.5) or weakly negative (–, values > –0.5 but < 0).

Species	Feeding guild	Estuary phase										Mean			Response		
		LK1	ES1	LG1	LK2	ES2	LG2	ES3	LG3	ES4	LG4	LK	ES	LG	LK	ES	LG
Residents																	
Little Grebe	I	1.45	-1.17	-1.26	0.67	-0.68	-0.08	-2.00	2.00	-1.69	0.00	1.06	-1.39	0.16	++	– –	+
Great Crested Grebe	P	-0.90	0.60	-0.47	0.65	-0.65	0.50	-1.56	1.16	-1.05	0.07	-0.12	-0.66	0.32	–	– –	+
Black-necked Grebe	I	-0.52	0.09	-1.34	-0.03	-1.37	1.93	-1.97	1.80	-2.00	2.00	-0.27	-1.31	1.10	–	– –	++
Red-knobbed Coot	H	1.67	-0.54	-1.80	1.30	-0.97	-0.42	-1.24	-1.35	-1.94	0.40	1.49	-1.17	-0.79	++	– –	– –
Cape Shoveler	I	0.84	-0.82	-0.54	1.18	-0.19	-0.75	-1.76	0.63	-1.23	-1.43	1.01	-1.00	-0.52	++	– –	– –
Yellow-billed Duck	H	0.56	-1.21	0.42	1.27	-0.67	-0.21	-1.50	0.27	-0.66	-1.36	0.91	-1.01	-0.22	++	– –	–
Egyptian Goose	H	0.88	-0.43	-0.35	0.91	-0.46	-0.43	-1.01	0.58	0.05	-0.31	0.90	-0.46	-0.13	++	–	–
Spur-winged Goose	H	-0.33	-0.45	0.79	1.22	-0.25	-0.20	-1.12	-0.71	0.78	0.55	0.44	-0.26	0.11	+	–	+
Red-billed Teal	H	-0.16	0.33	-1.23	0.18	0.72	0.40	-1.73	-0.67	-2.00	–	0.01	-0.67	-0.50	+	--	--
Cape Teal	I	0.06	0.41	-0.06	-0.92	-0.91	1.15	-2.00	–	–	–	-0.43	-0.83	0.54	-	--	++
Southern Pochard	H	-1.43	1.01	-1.95	–	1.86	-2.00	2.00	-0.67	-2.00	–	-1.43	0.72	-1.54	--	++	--
African Darter	P	1.01	-0.32	-0.70	0.95	0.57	-1.14	-1.58	0.63	0.33	-1.76	0.98	-0.25	-0.74	++	–	– –
Reed Cormorant	P	0.40	-0.40	0.22	0.65	-0.11	0.07	-1.26	1.37	-1.80	0.75	0.52	-0.89	0.60	++	– –	++
Cape Cormorant	P	0.78	-1.91	1.84	0.15	0.07	1.41	-1.72	1.79	-1.77	-1.25	0.46	-1.33	0.95	+	– –	++
White-breasted Cormorant	P	0.53	-1.22	0.50	0.25	-0.13	0.69	-0.83	0.46	-1.49	-0.12	0.39	-0.92	0.38	+	– –	+
Great White Pelican	P	0.35	0.54	0.59	0.29	1.18	-0.16	-1.43	0.54	1.12	-0.09	0.32	0.35	0.22	+	+	+
Cattle Egret	I	0.12	-1.44	-0.14	1.56	-2.00	2.00	-1.20	0.40	-0.40	-2.00	0.84	-1.26	0.06	++	– –	+
Hadeda Ibis	I	0.84	-0.97	0.57	0.09	-0.97	1.01	-1.54	1.62	-1.12	-0.91	0.46	-1.15	0.57	+	– –	++
Grey Heron	P	0.63	-0.75	0.01	0.24	0.35	-0.08	-1.16	0.41	-1.11	0.46	0.44	-0.67	0.20	+	– –	+
Little Egret	I	0.16	0.73	-0.67	-0.32	0.88	-0.03	-1.18	1.34	-0.98	0.63	-0.08	-0.14	0.32	–	–	+
African Sacred Ibis	I	0.06	1.34	-0.57	-0.65	0.68	0.25	1.17	-0.47	-1.49	1.39	-0.30	0.42	0.15	–	+	+
African Spoonbill	I	-0.08	0.73	0.45	-1.14	-0.74	1.61	-1.00	-0.21	0.07	-2.00	-0.61	-0.23	-0.04	– –	–	–
Greater Flamingo	I	-1.62	1.57	-1.03	-1.72	-1.92	1.99	-2.00	2.00	1.64	-0.63	-1.67	-0.18	0.58	– –	–	++
Blacksmith Lapwing	I	0.03	-0.11	-0.02	0.14	0.36	-0.18	-0.77	0.48	-0.34	-1.66	0.08	-0.22	-0.34	+	–	–
Black-winged Stilt	I	0.18	0.21	-0.21	-0.02	-0.49	1.06	-0.85	-0.62	0.24	-1.80	0.08	-0.22	-0.39	+	–	–
Three-banded Plover	I	0.15	-0.12	0.49	-0.73	-0.67	0.98	-0.97	-1.20	0.00	1.89	-0.29	-0.44	0.54	–	–	++
White-fronted Plover	I	-0.46	-1.09	1.28	-0.13	-1.09	1.52	-0.08	-1.94	1.20	0.00	-0.30	-0.26	0.21	–	–	+
Kittlitz's Plover	I	-0.71	1.36	0.78	-0.57	0.28	0.67	-0.19	-1.81	1.69	1.41	-0.64	0.79	0.26	– –	++	+
Pied Kingfisher	P	0.56	-0.71	0.24	0.05	-0.21	0.45	-0.83	0.64	-0.10	-0.07	0.31	-0.46	0.32	+	–	+
Hartlaub's Gull	I	-0.33	0.39	-0.55	0.12	0.85	-0.12	-0.46	-0.62	0.82	-0.97	-0.10	0.40	-0.57	–	+	– –
Kelp Gull	I	0.00	0.71	0.20	-0.28	0.42	-0.35	0.60	0.83	-0.14	-0.16	-0.14	0.40	0.13	–	+	+
Caspian Tern	P	0.14	-0.96	0.94	0.25	-1.29	0.84	-0.70	0.45	-0.81	1.00	0.20	-0.94	0.81	+	– –	++
Swift Tern	P	0.05	-1.48	0.90	-0.05	0.14	1.54	-1.31	0.86	-2.00	2.00	0.00	-1.16	1.33		– –	++
Palearctic migrants																	
Curlew Sandpiper	I	-1.35	1.61	0.22	1.71	-1.33	-0.13	-2.00	–	–	2.00	0.18	-0.57	0.70	–	– –	++
Little Stint	I	-0.10	1.78	0.42	-1.68	-1.08	1.35	-2.00	–	–	2.00	-0.89	-0.44	1.26	– –	–	++
Common Greenshank	I	-1.20	1.17	-0.25	-1.75	1.01	0.85	1.48	-2.00	2.00	-0.24	-1.47	1.42	-0.41	– –	++	–
Sandwich Tern	P	-0.86	-0.53	-0.62	1.10	-2.00	2.00	1.83	-2.00	-	2.00	0.12	-0.23	0.34	+	–	+
Common Tern	P	-0.73	1.20	0.05	0.46	-1.00	1.51	1.26	-1.98	0.29	1.83	-0.14	0.44	0.35	–	+	+

Table 4.9 Summary of linear model selection analysis for waterbird variability at the Bot River Estuary, 2002–2010. Covariate labels: wl = water-level, s = salinity, mbp = months between phases, mr = mean run-off. r^2 = adjusted correlation coefficients, P = model probability and AIC = Akaike's An Information Criterion.

Model and co-variates	r^2	P	AIC[1]
Model 1 : $\beta_0 + \beta_{wl.}X$	0.482	0.018	20.4
Model 2 : $\beta_0 + \beta_{s.}X$	0.394	0.039	22.1
Model 3 : $\beta_0 + \beta_{wl} + \beta_s X$	0.354	0.072	22.3
Model 4 : $\beta_0 + \beta_{wl.} + B_{mbp}X$	0.355	0.071	22.3
Model 5 : $\beta_0 + \beta_{mbp.}X$	0.288	0.051	22.7
Model 6 : $\beta_0 + \beta_{mr} + \beta_{mbp} + \beta_s X$	0.164	0.315	26.0
Model 7 : $\beta_0 + \beta_{mr}X$	-0.107	0.850	27.5

[1] Model selection was based on Akaike's An Information Criterion (AIC). A lower AIC value indicates a better model.

Table 4.10 Species of conservation importance at Bot River Estuary based on maximum counts from 55 surveys. Ramsar 1% levels, sub-regional IBA levels and provincial (Western Cape) thresholds are given. Species are sorted in descending order of the global 1% threshold level. Species in bold are included in the South African Red Data Book (Barnes 2000).

Species	Max. count	Threshold		
		Ramsar 1%[1]	IBA 0.5%[2]	Western Cape[3]
Caspian Tern	88	5.9% (13)	14	15.7%
Greater Flamingo	2884	3.8% (7)	7	14.8%
Great Crested Grebe	356	3.7% (22)	11	26.6%
Swift Tern	704	3.5% (6)	3	12.2%
Hartlaub's Gull	728	2.4% (12)	14	9.6%
White-breasted Cormorant	247	2.1% (15)	13	5.0%
Cape Shoveler	720	2.1% (5)	8	8.9%
Yellow-billed Duck	2030	2.0% (3)	8	14.2%
Red-knobbed Coot	15352	1.5% (3)	6	20.6%
Black-necked Grebe	199	1.3% (2)	2	6.1%
Kelp Gull	867	1.2% (1)	6	6.6%
Sandwich Tern	2059	1.2% (1)	1	49.9%
Great White Pelican	222	1.1% (1)	6	6.8%
Black-winged Stilt	125	–	4	–
Southern Pochard	390	–	2	23.5%
White-backed Duck	134	–	2	19.5%
White-fronted Plover	106	–	1	6.5%
Reed Cormorant	–	–	–	15.4%
African Spoonbill	–	–	–	14.4%
Purple Heron	–	–	–	9.9%
Common Tern	–	–	–	9.9%
Little Grebe	–	–	–	9.9%
African Snipe	–	–	–	8.6%
Cattle Egret	–	–	–	8.2%
Yellow-billed Egret	–	–	–	8.0%
Bank Cormorant	–	–	–	8.0%
Grey Heron	–	–	–	7.1%
Cape Cormorant	–	–	–	7.0%
Water Thick-knee	–	–	–	6.8%
African Sacred Ibis	–	–	–	6.3%
Spur-winged Goose	–	–	–	6.0%
African Darter	–	–	–	5.3%
Black Stork	–	–	–	5.3%
Little Egret	–	–	–	5.2%
African Black Duck	–	–	–	5.1%

[1] Figures represent the percentage of the estimated global* or Southern African# population based on the maximum count. Numbers in parentheses represent the number of counts which met or surpassed the 1% threshold level. Calculated from Wetlands International (2006).

[2] Figures represent the number of counts which met or surpassed the Sub-regional IBA level (0.5% threshold) for southern Africa (Barnes 1998) but did not surpass the 1% global threshold level.

[3] Value represents the percentage of the estimated provincial population and based on the maximum count. Estimates sourced and calculated from Coordinated Waterbird Counts, Avian Demography Unit, unpublished data (2006)

Table 4.11 Waterbird Conservation Value (WCV) scores for 22 waterbirds at the Bot River Estuary from February 2002–February 2010. Only species that had at least one score index value ≥ 0.1 during any one phase are listed. Scores equalling or surpassing the 0.5% and/or 1.0% thresholds are highlighted in italics and bold respectively. For estuarine phase abbreviations refer to Table 4.2.

Species	Estuarine phase											Mean WCV score		
	LK1	ES1	LG1	LK2	ES2	LG2	LK3	ES3	LG3	ES4	LG4	Lake	Estuary	Lagoon
Great Crested Grebe	**1.23**	**2.29**	**1.42**	*0.54*	0.28	*0.50*	*0.90*	0.11	0.42	0.13	0.14	*0.89*	*0.70*	*0.62*
Caspian Tern	**1.10**	0.39	**1.08**	**1.24**	0.27	*0.76*	*0.83*	0.40	*0.63*	0.27	*0.80*	**1.06**	0.33	*0.82*
White-breasted Cormorant	*0.95*	0.23	0.39	*0.67*	*0.58*	**1.00**	**1.54**	*0.64*	1.02	0.15	0.13	**1.05**	0.40	*0.63*
Red-knobbed Coot	*0.77*	0.44	0.02	0.26	0.09	0.07	0.28	0.07	0.01	0.00	0.00	0.43	0.15	0.03
Cape Shoveler	*0.68*	0.29	0.17	0.40	0.33	0.17	*0.59*	0.04	0.07	0.02	0.00	*0.56*	0.17	0.10
Hartlaub's Gull	*0.66*	*0.98*	*0.56*	0.40	*0.99*	*0.74*	*0.99*	*0.62*	0.33	*0.78*	0.27	*0.68*	*0.84*	0.47
Yellow-billed Duck	*0.59*	0.15	0.22	0.40	0.20	0.14	*0.71*	0.10	0.13	0.07	0.01	*0.57*	0.13	0.13
Swift Tern	0.34	0.05	0.13	0.14	0.16	**1.61**	**1.20**	0.25	*0.62*	0.00	*0.68*	*0.56*	0.12	*0.76*
Black-necked Grebe	0.28	0.31	0.06	0.04	0.01	0.08	0.38	0.00	0.06	0.00	0.01	0.23	0.08	0.05
Little Grebe	0.28	0.07	0.02	0.10	0.05	0.04	0.09	0.00	0.02	0.00	0.00	0.16	0.03	0.02
White-backed Duck	0.24	0.05	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.01	0.00
Greater Flamingo	0.22	**1.84**	*0.59*	0.06	0.00	*0.71*	0.04	0.00	0.05	0.49	0.26	0.11	*0.58*	0.40
Black-winged Stilt	0.13	0.16	0.13	0.16	0.10	0.40	0.31	0.12	0.07	0.08	0.00	0.20	0.12	0.15
White-fronted Plover	0.12	0.04	0.17	0.10	0.03	0.15	0.20	0.18	0.00	0.01	0.01	0.14	0.06	0.08
Southern Pochard	0.11	0.34	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.04	0.09	0.00
African Black Oystercatcher	0.10	0.12	0.11	0.12	0.16	0.19	0.05	0.10	0.10	0.02	0.38	0.09	0.10	0.19
Kelp Gull	0.10	0.21	0.26	0.26	0.40	0.32	0.21	0.39	*0.95*	*0.82*	*0.70*	0.19	0.46	*0.56*
Spur-winged Goose	0.05	0.03	0.08	0.05	0.04	0.03	0.15	0.04	0.02	0.04	0.08	0.08	0.04	0.05
Sandwich Tern	0.05	0.03	0.01	0.01	0.00	0.01	0.03	*0.61*	0.00	0.00	0.04	0.03	0.16	0.02
Great White Pelican	0.03	0.05	0.09	0.13	*0.51*	0.22	0.59	0.10	0.17	*0.60*	*0.55*	0.25	0.32	0.26
Kittlitz's Plover	0.01	0.05	0.12	0.06	0.08	0.15	0.09	0.07	0.00	0.04	0.24	0.05	0.06	0.13
Common Tern	0.01	0.03	0.03	0.02	0.01	0.05	0.06	0.27	0.00	0.00	0.05	0.03	0.08	0.03
Additional species[1]	0.30	0.22	0.20	0.24	0.23	0.42	0.38	0.17	0.35	0.16	0.33	0.31	0.19	0.32
Total	**8.37**	**8.38**	**5.85**	**5.40**	**4.53**	**7.75**	**9.58**	**4.28**	**5.03**	**3.69**	**4.70**	**7.78**	**5.22**	**5.83**

[1] This category refers to the sum of scores for all remaining species.

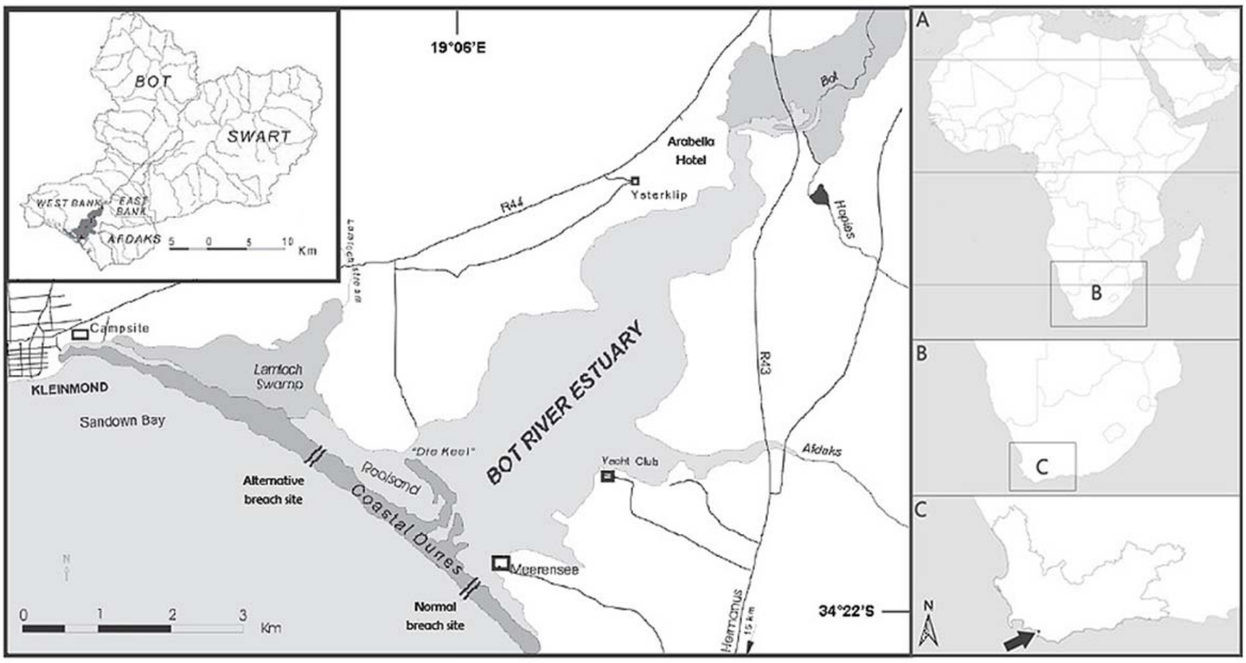

Figure 4.1 Bot River Estuary and its link to the Kleinmond Estuary via Die Keel and the Lamloch Swamps. Inset shows the three catchments (Bot River, Swart River and Afdaks River) which drain into the estuary. Modified from van Niekerk et al. 2005.

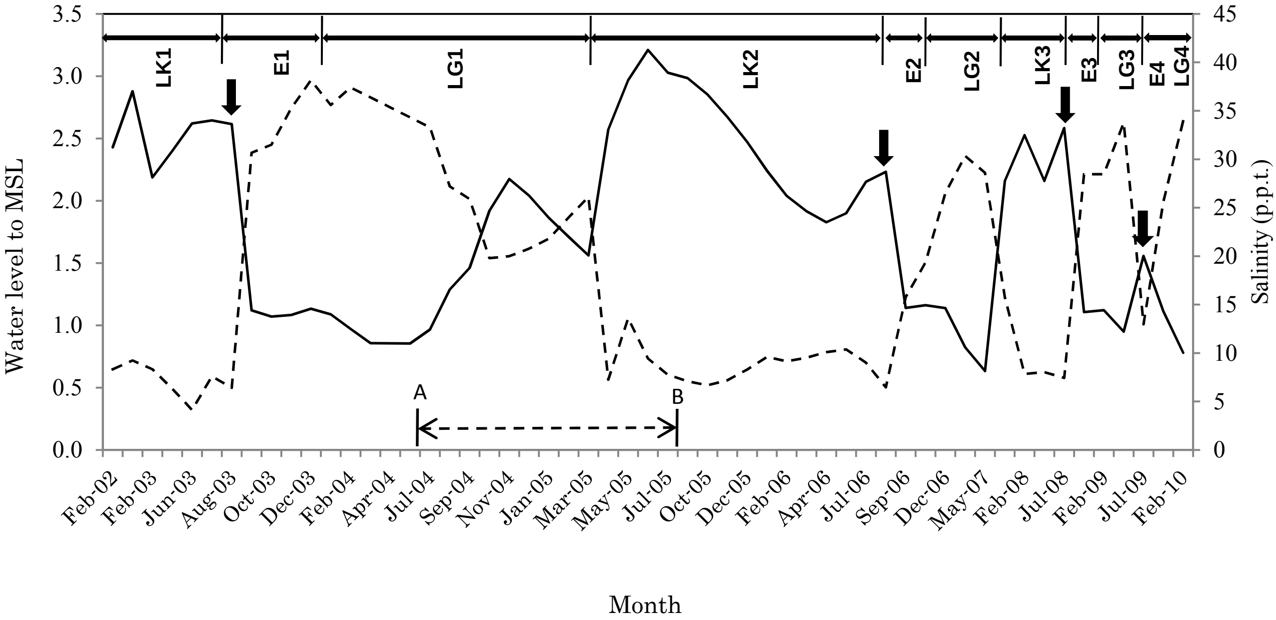

Figure 4.2 The 11 hydrological phases of the Bot River Estuary from February 2002–February 2010 in relation to water-level (solid line) and salinity (dashed line). Values from February 2003–December 2006 are monthly or quarterly; values after December 2006 are at less frequent intervals. A–B represents the conditions during the 'normal' (i.e. non-breaching) annual cycle of the estuary. Black arrows indicate when a breach occurred. For explanation of the codes refer to Table 4.2.

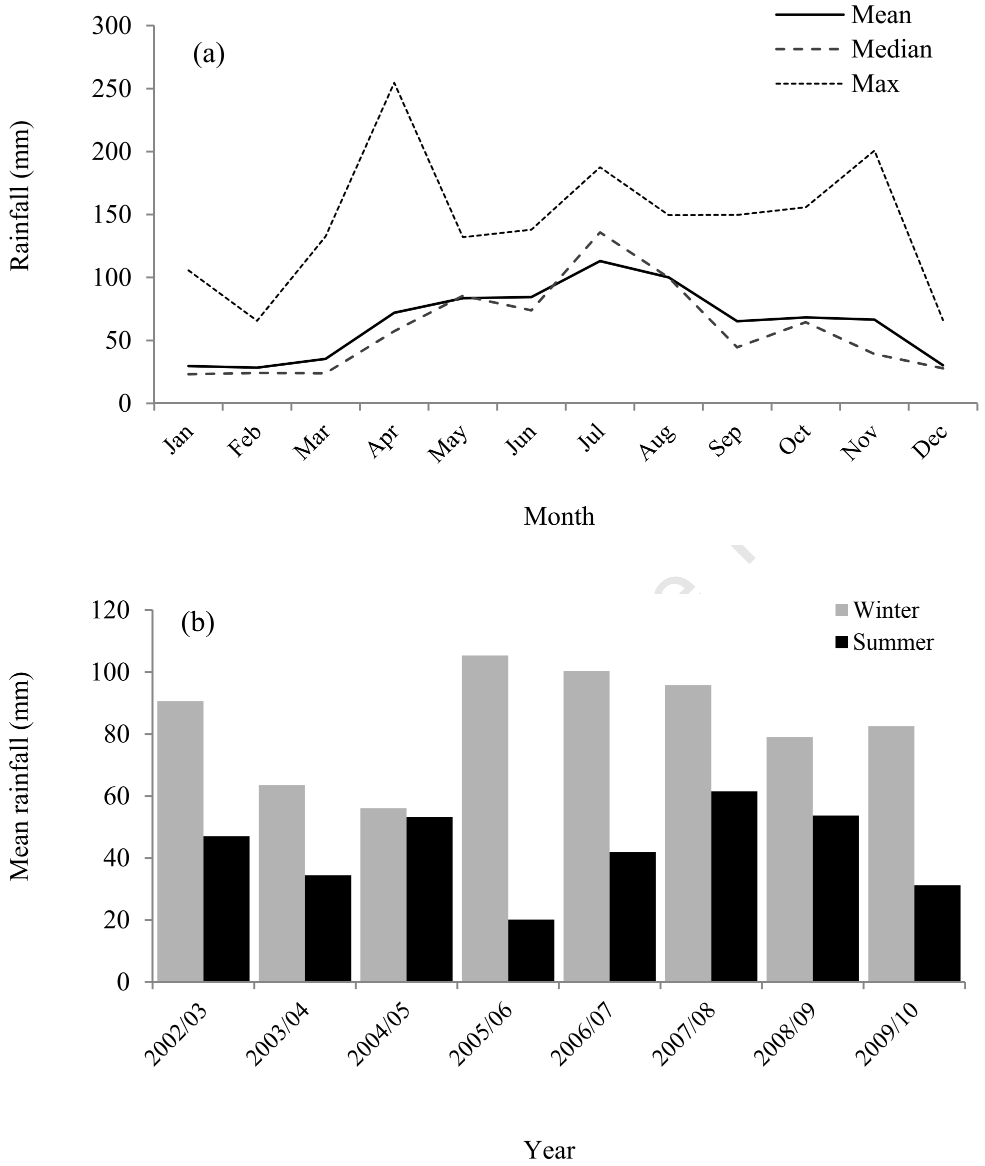

Figure 4.3 (a) Monthly mean, median and maximum monthly rainfall from weather station at Haasvlakte, near Caledon, from 2002–2009; (b) Inter-annual variation in mean summer and winter rainfall from Haasvlakte, 2002/03–2009/10.

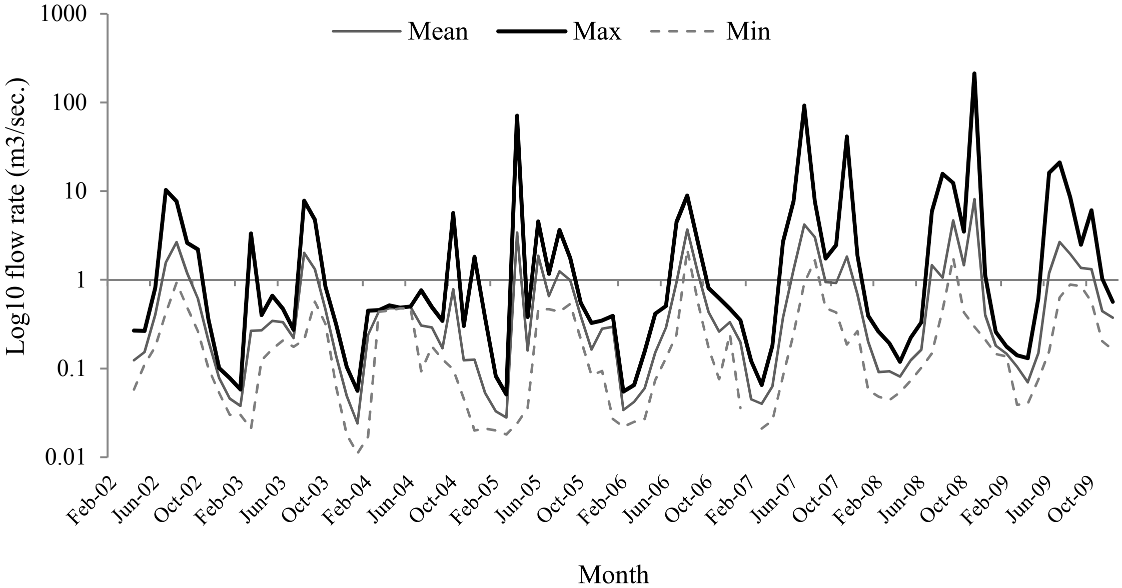

Figure 4.4 Mean, maximum and minimum flow rate of the Bot River upstream from the estuary between February 2002–February 2010.

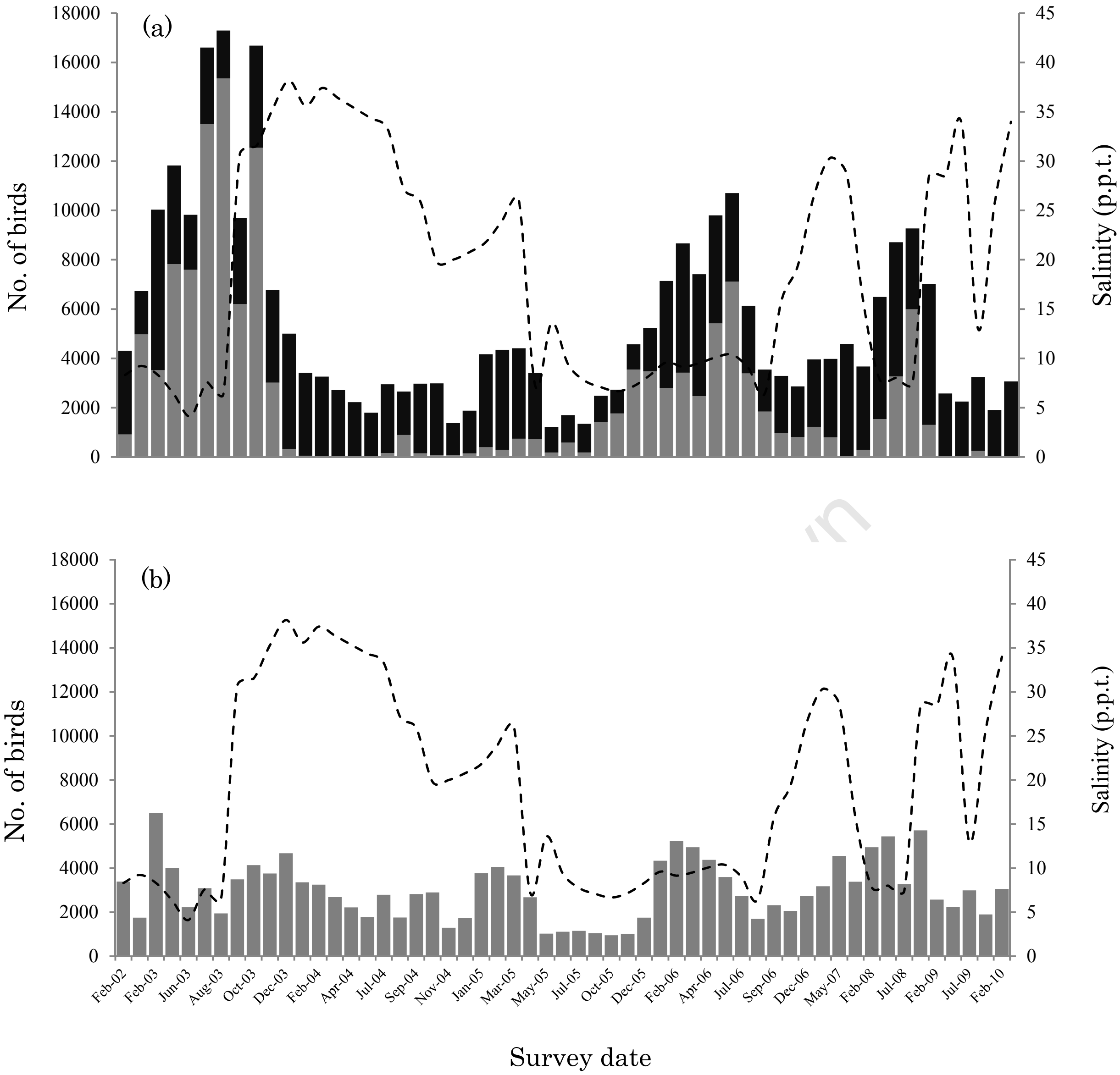

Figure 4.5 Changes in total waterbird abundance in relation to changes in salinity (dashed line) at the Bot River Estuary from February 2002–February 2010 with (a) Red-knobbed Coot (dark bars) included and (b) Red-knobbed Coot excluded. Both graphs shown at the same scale to facilitate comparison.

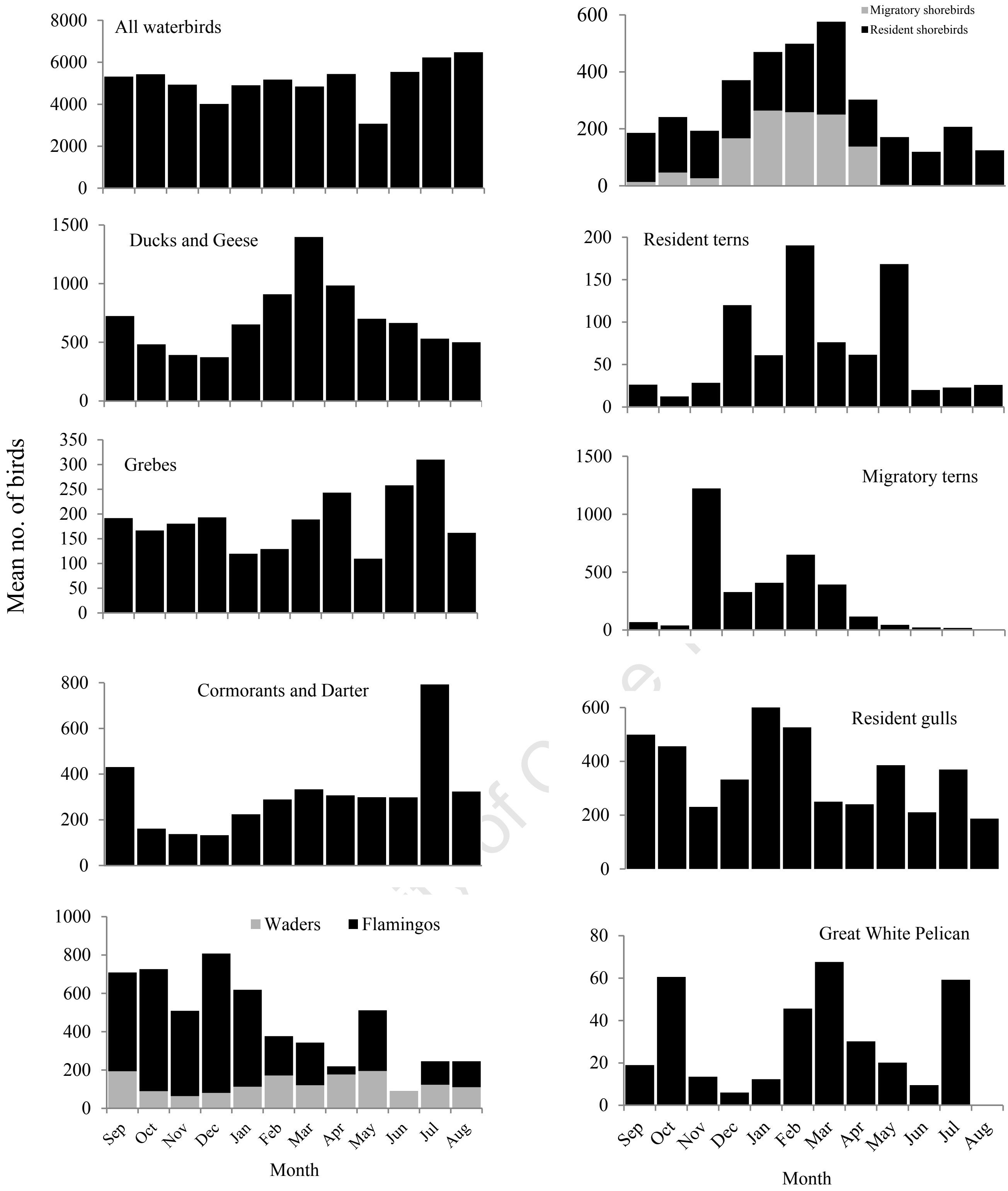

Figure 4.6 Mean monthly abundance of all waterbirds and the main waterbird groups at the Bot River Estuary from February 2002–February 2010.

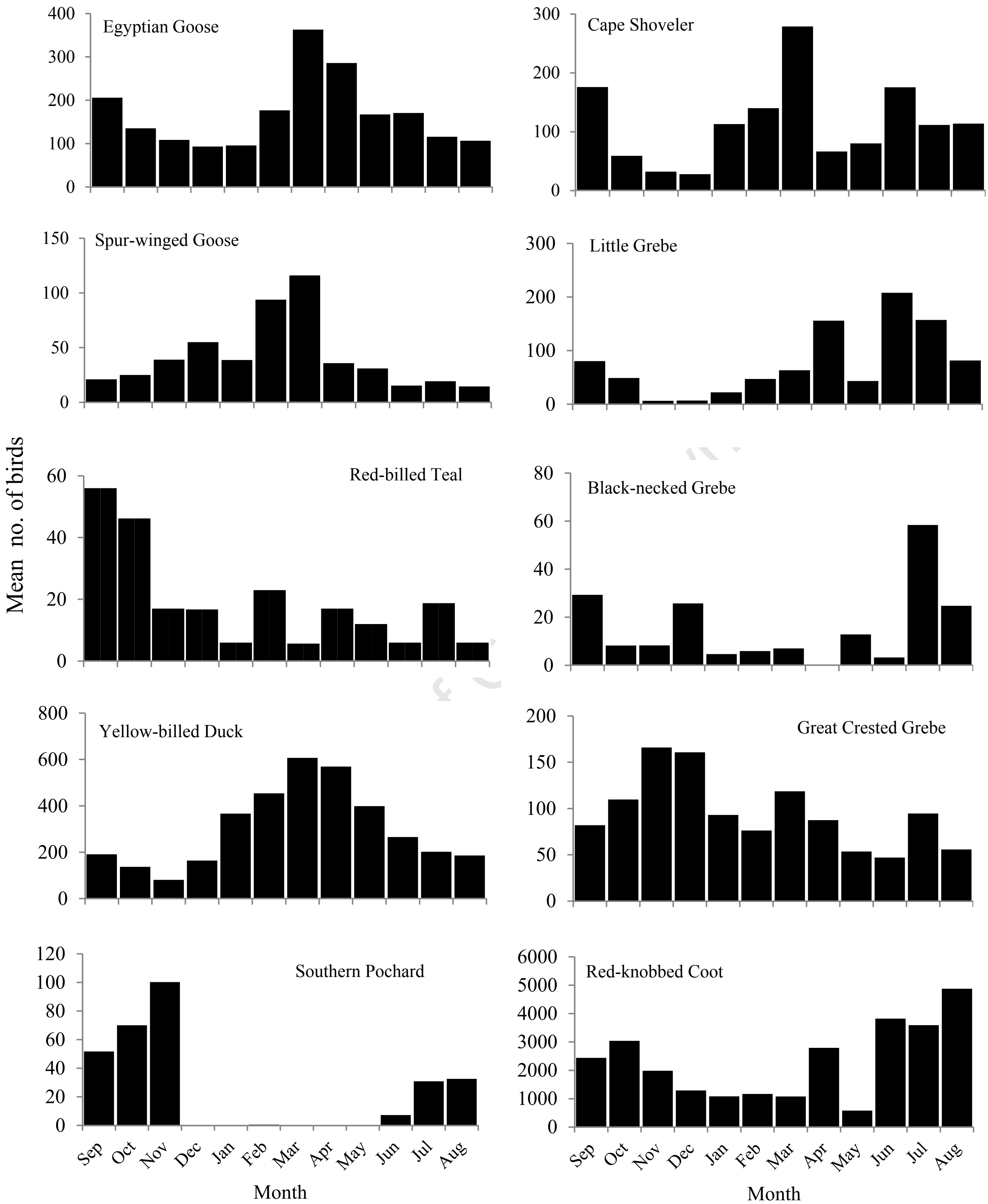

Figure 4.7 Mean monthly abundance of 10 waterfowl species at the Bot River Estuary from February 2002–February 2010.

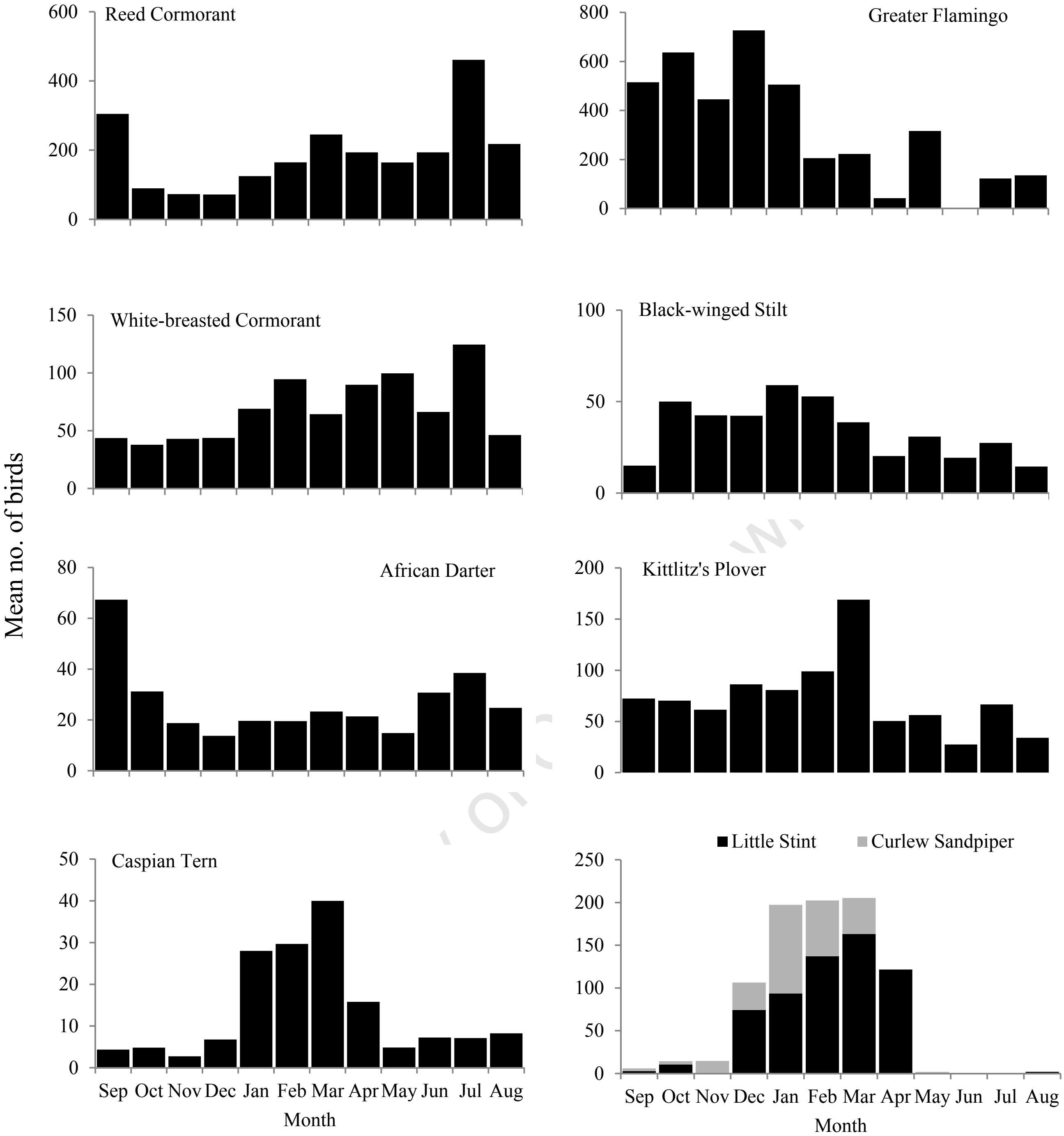

Figure 4.8 Mean monthly abundance of nine waterbirds at the Bot River Estuary from February 2002–February 2010.

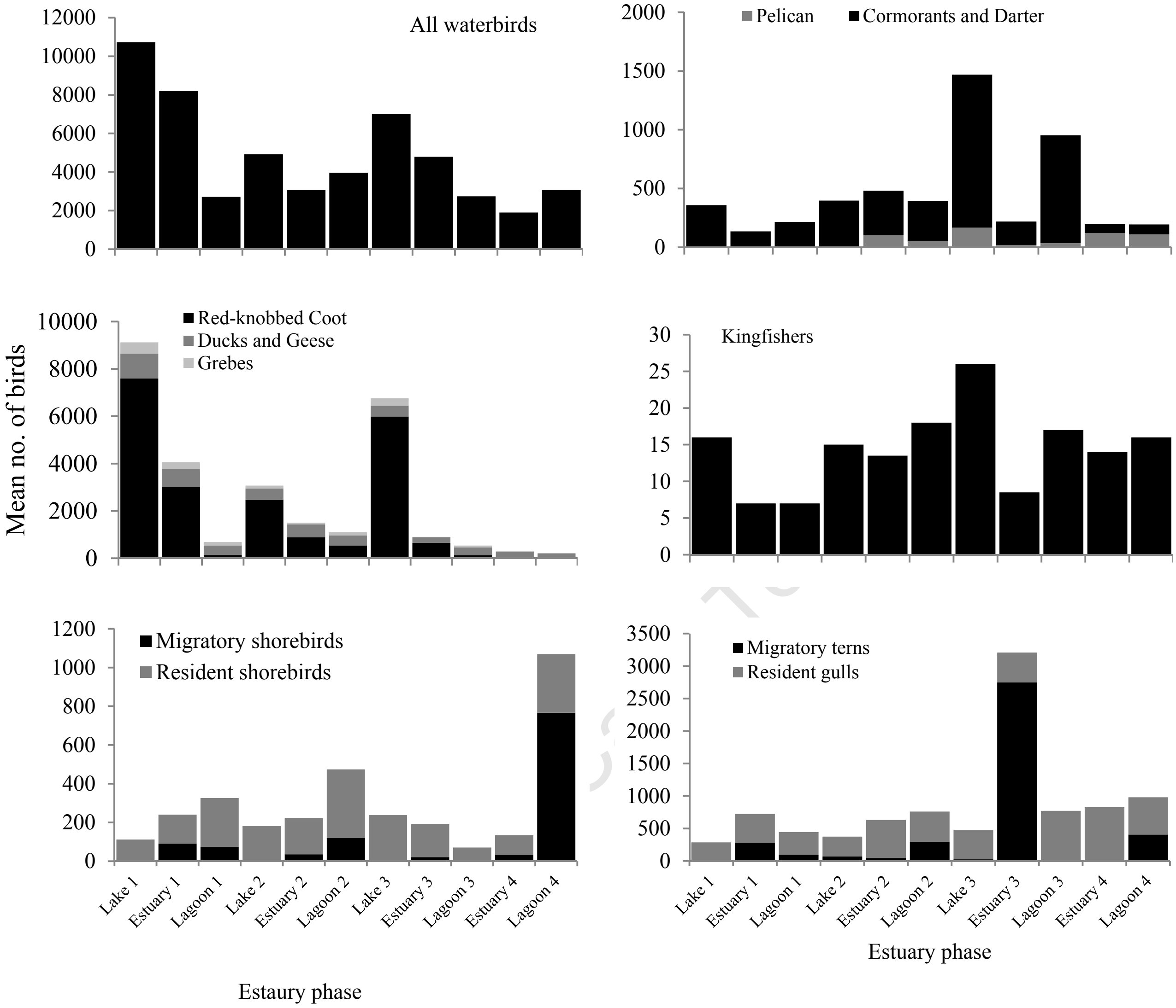

Figure 4.9 Mean abundance of different waterbird groups during the 11 phases of the Bot River Estuary from February 2002–February 2010.

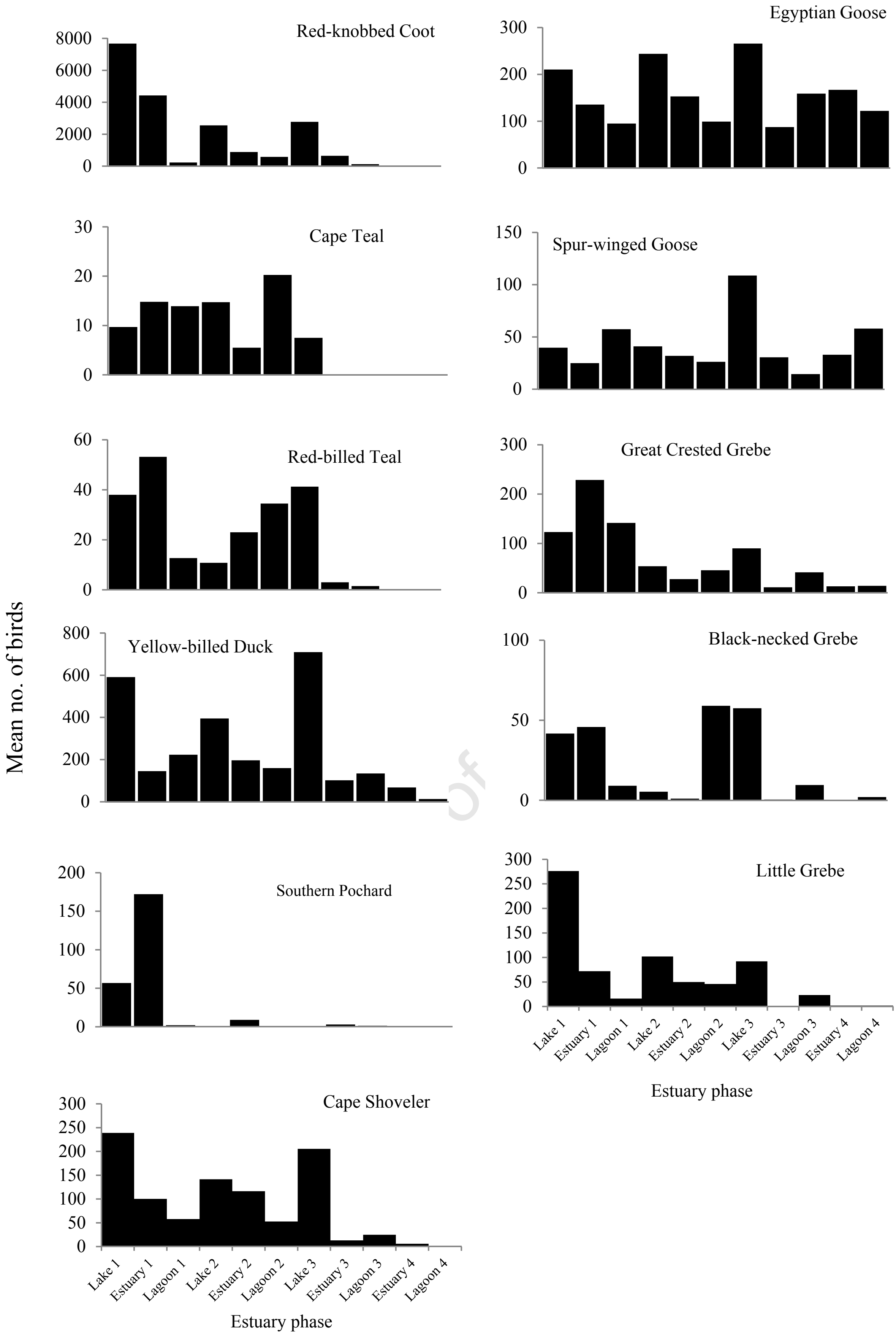

Figure 4.10 Mean abundance of 11 waterfowl species during the 11 phases of the Bot River Estuary from February 2002–February 2010.

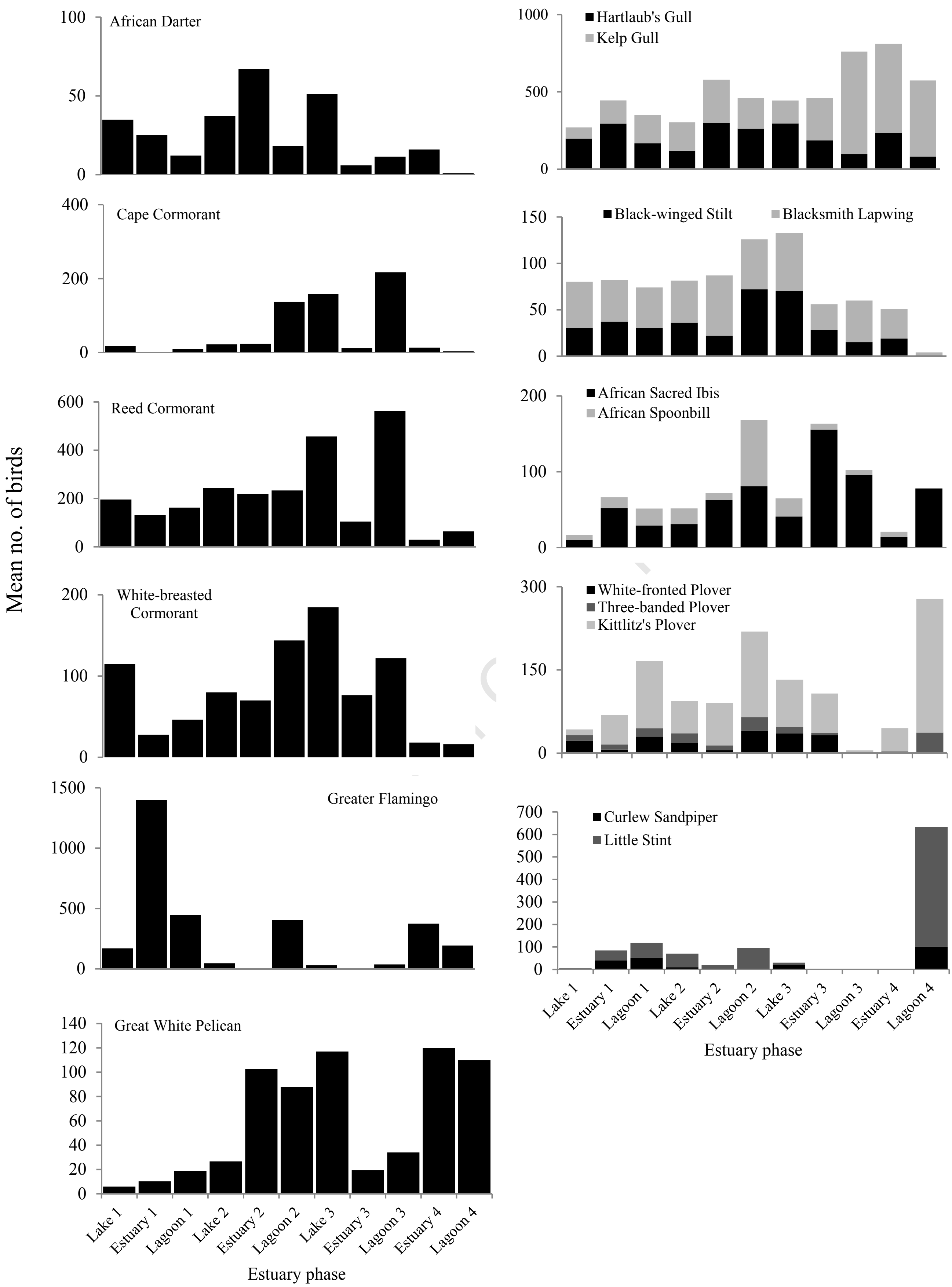

Figure 4.11 Mean abundance of 17 waterbird species during the 11 phases of the Bot River Estuary from February 2002–February 2010.

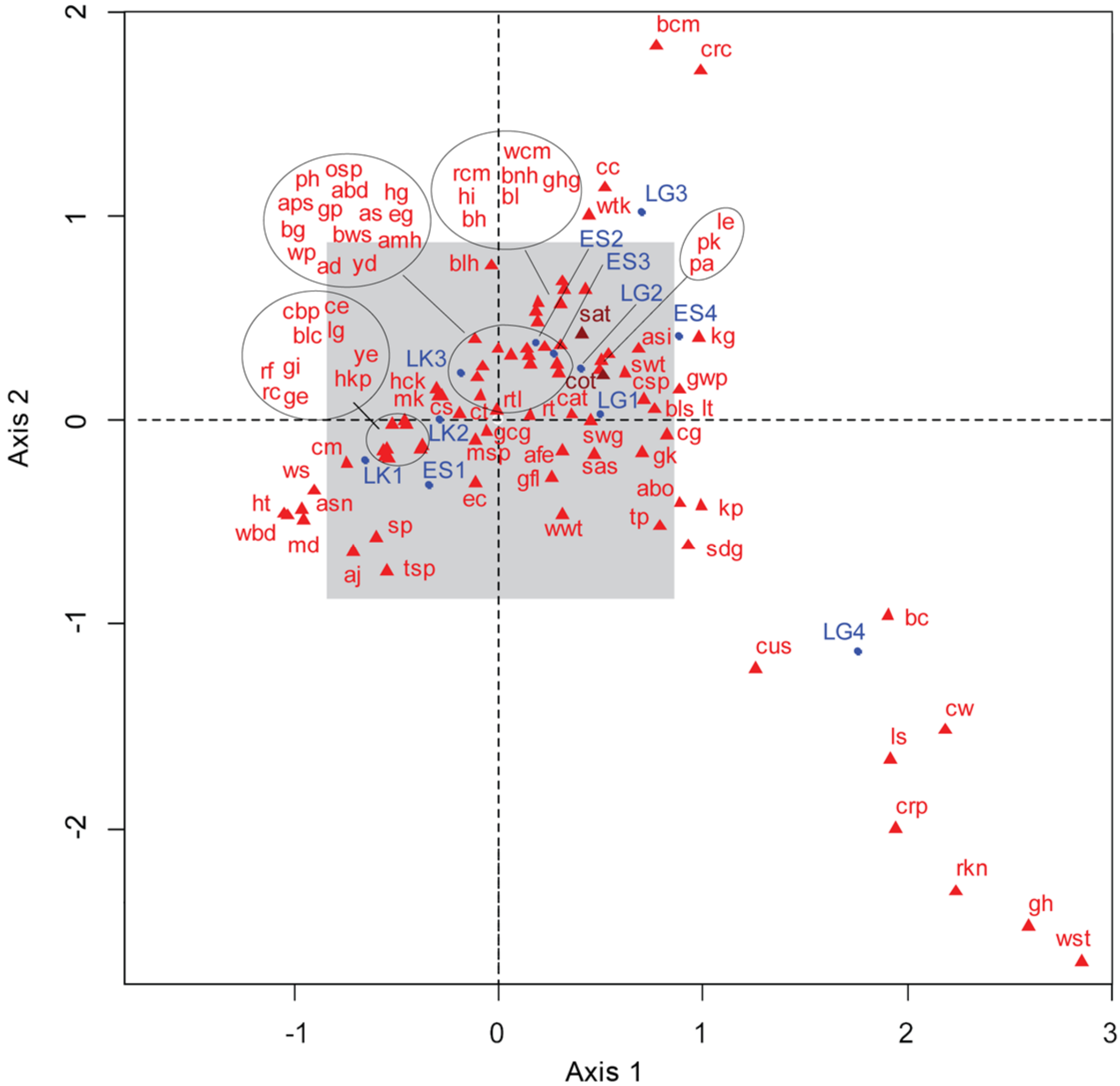

Figure 4.12 Plot of mean species abundance and estuarine phase at the Bot River estuary (2002–2010) based on correspondence analysis. The plot represents the first principal plane of the correspondence analysis. The horizontal axis accounts for 45.49% of the inertia, and the vertical axis accounts for 21.85% of the inertia. The boxed area is detailed in Figure 4.13.

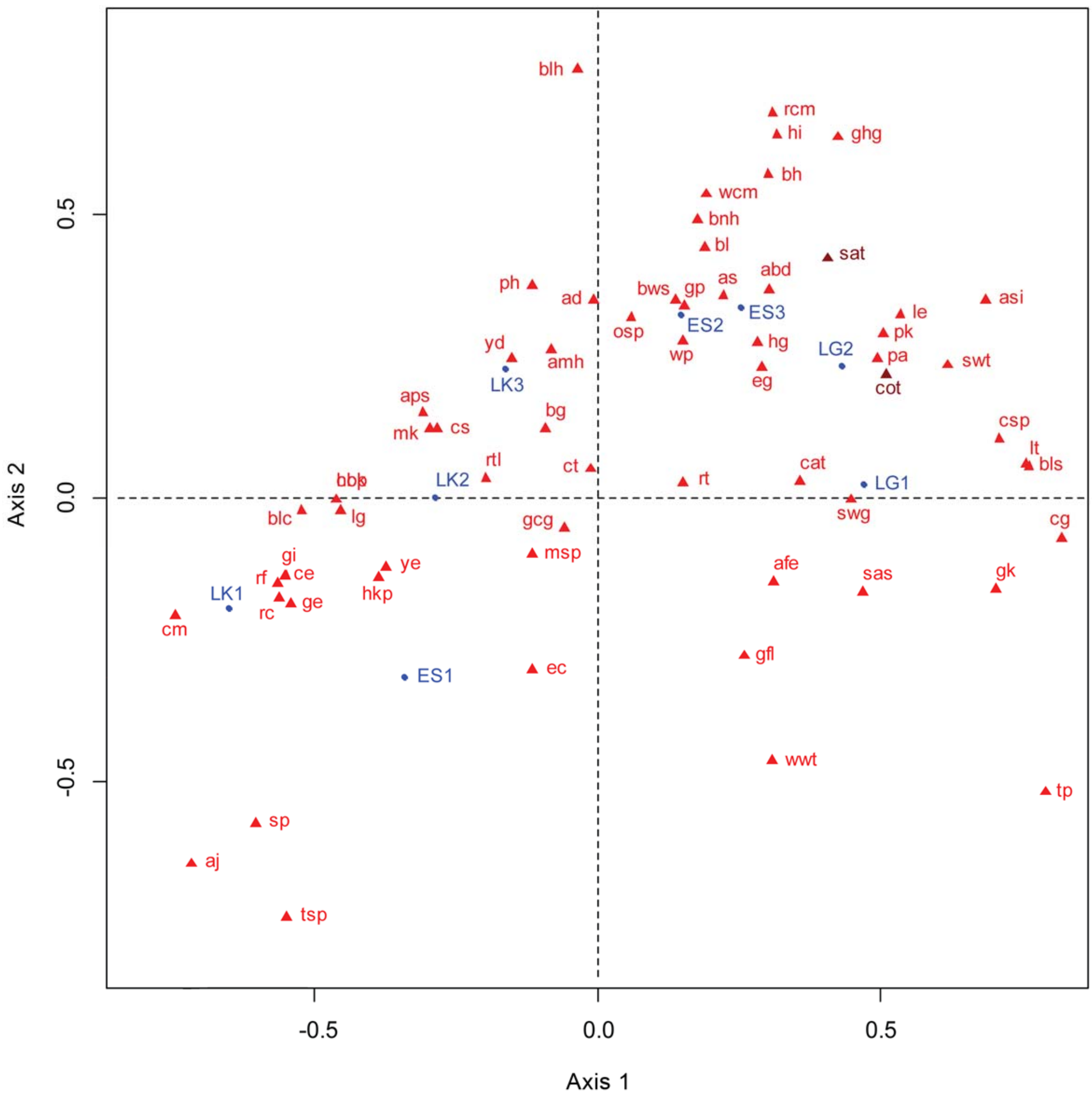

Figure 4.13 Plot of mean species abundance and estuarine phase at the Bot River estuary (2002–2010) based on correspondence analysis (zoomed in view from inset in Figure 4.12). The plot represents the first principal plane of the correspondence analysis. The horizontal axis accounts for 45.49% of the inertia, and the vertical axis accounts for 21.85% of the inertia.

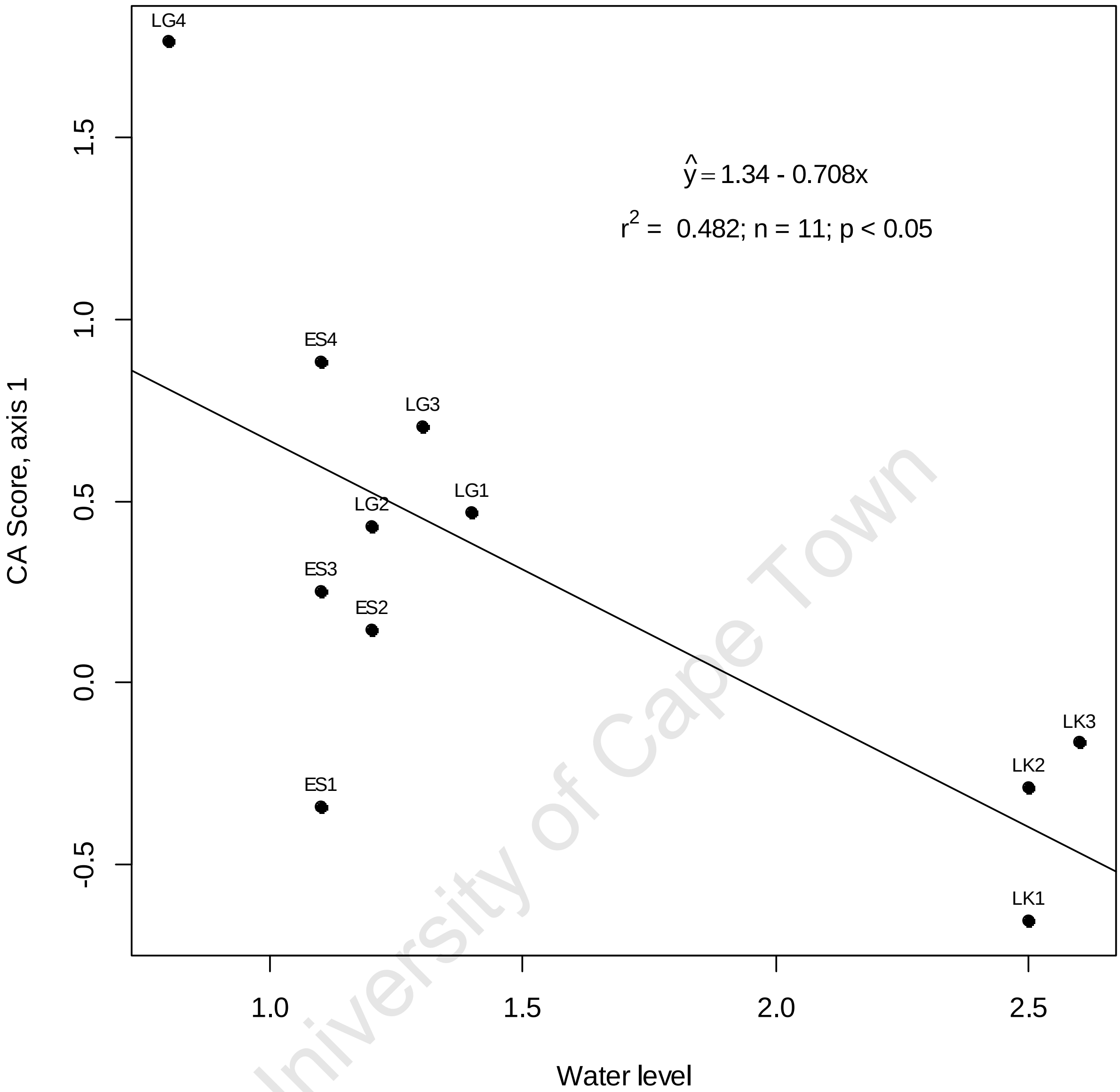

Figure 4.14 Plot showing the relationship between the estuarine phase CA scores (derived from the first axis, Figure 4.12) and water-level at the Bot River Estuary, 2002–2010.

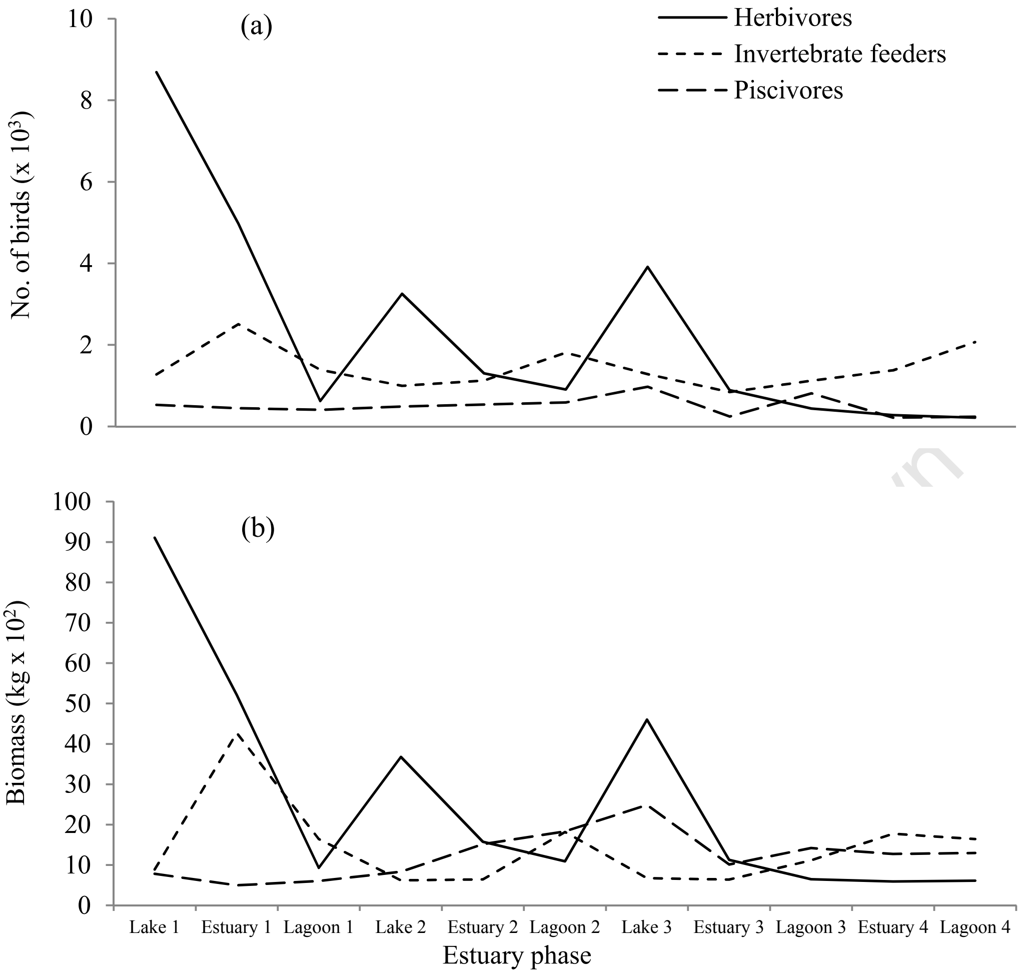

Figure 4.15 Mean (a) abundance and (b) biomass of herbivores, invertebrate feeders and piscivores during the 11 phases of the Bot River Estuary from February 2002–February 2010.

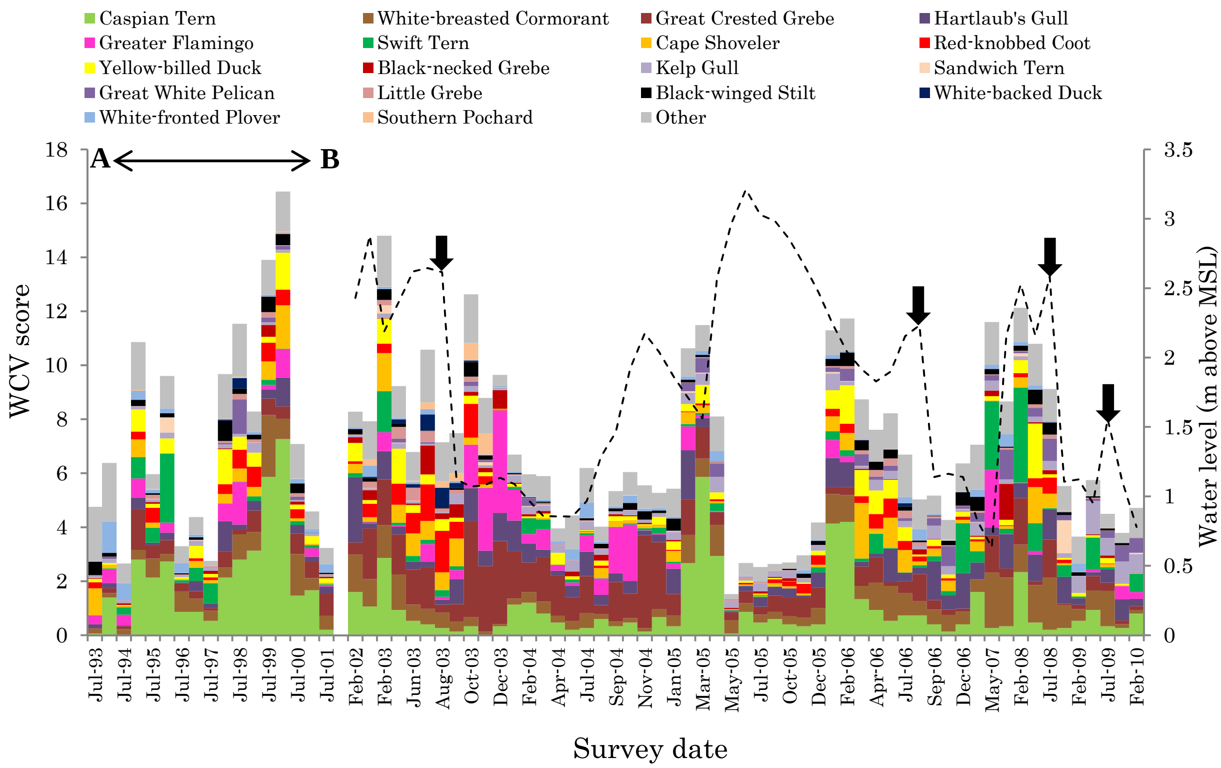

Figure 4.16 Colour-coded histogram to show the change in the Waterbird Conservation Value (WCV) score at the Bot River Estuary from 1993–2010. Species listed are those that reached or surpassed the 0.5% or 1% threshold level at least once. The line A–B represents six-monthly surveys from1993–July 2002. The dashed line represents water–level and the black down arrows indicate when a breach occurred. MSL = mean sea level.

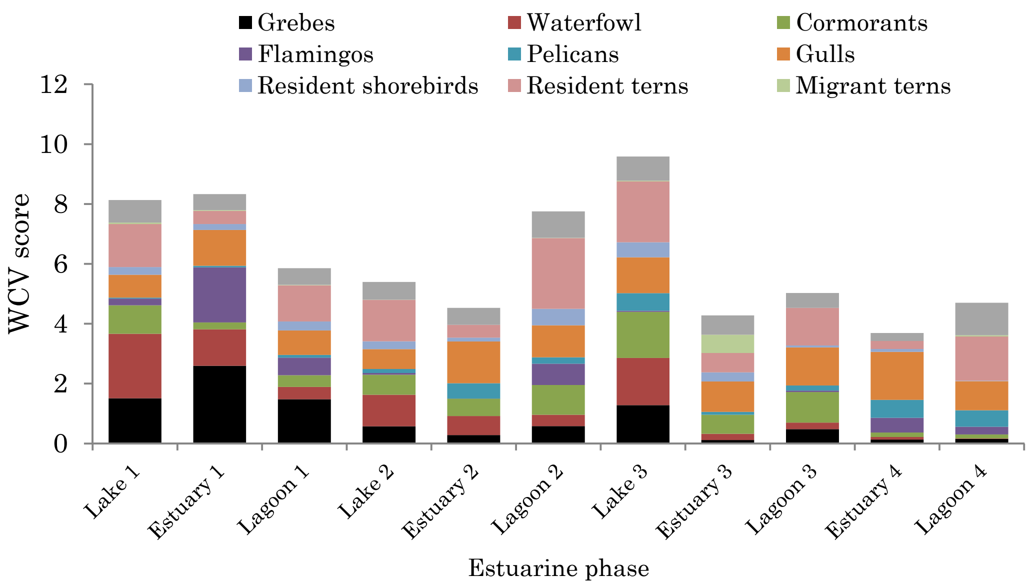

Figure 4.17 Changes in the WCV scores between the 11 different estuarine phases at the Bot River estuary, 2002–2010. Species groups for which WCV scores were greater than 1.0 are shown. Species breakdowns are shown in Figures 4.18a, b.

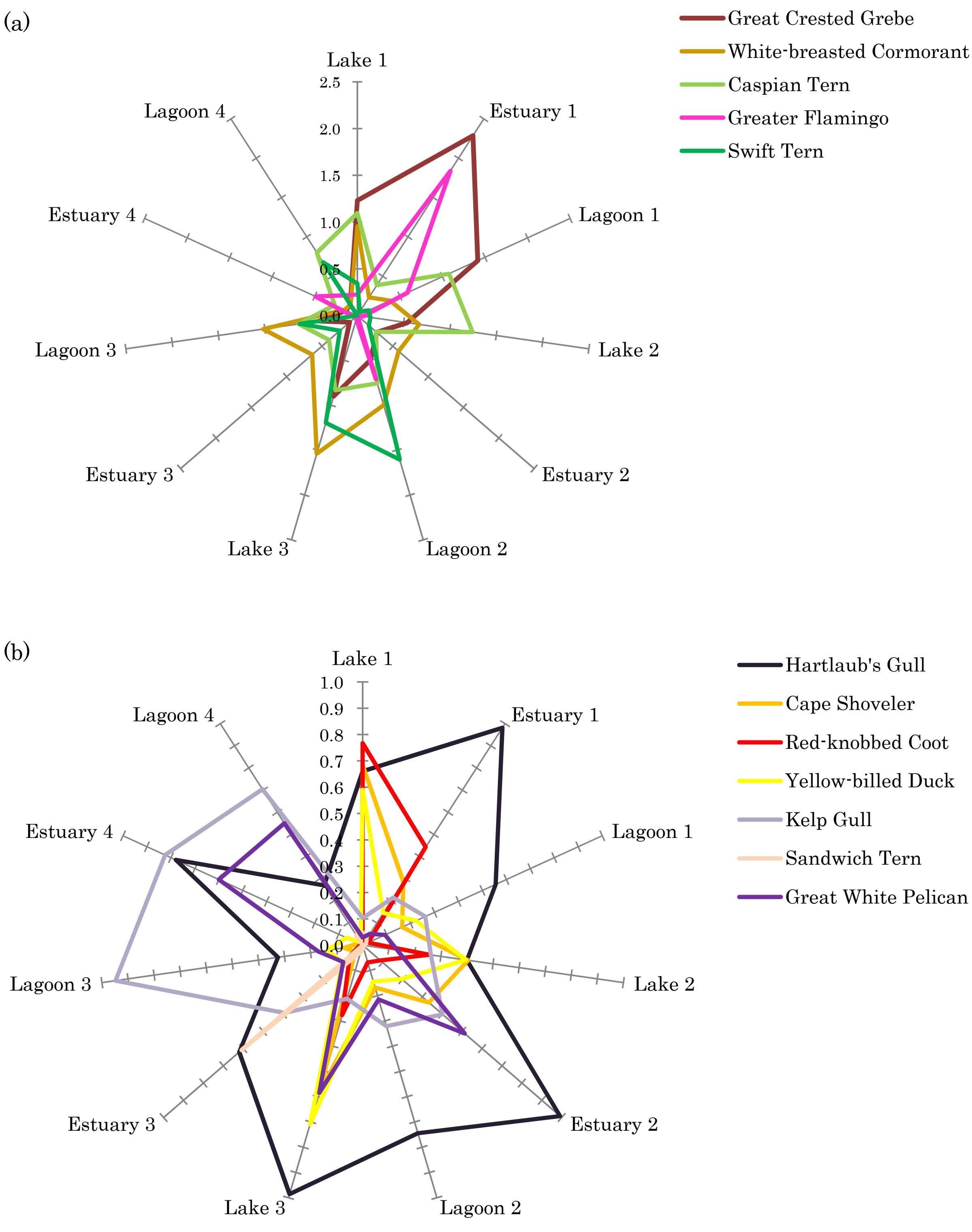

Figure 4.18 Colour-coded radar plots showing the change in Waterbird Conservation Value (WCV) scores (vertical axis) between the 11 phases of the Bot River estuary, February 2002–February 2010, for (a) species with WCV scores ≥ 1 (i.e. species meeting Ramsar thresholds) and (b) species with WCV scores ≥ 0.5 and < 1.0 (i.e. species meeting Sub-regional IBA thresholds)

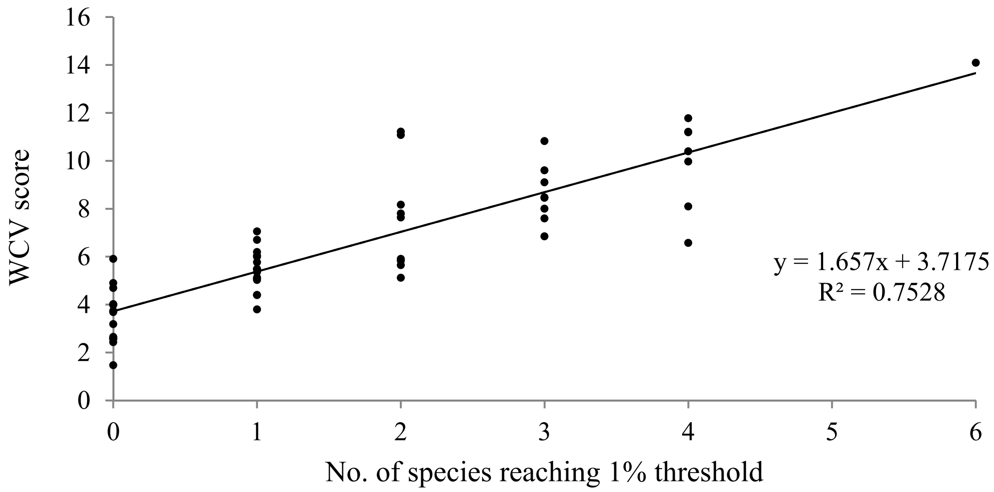

Figure 4.19 The relationship between the monthly Waterbird Conservation Value (WCV) score and the number of species reaching 1% thresholds at the Bot River Estuary, 2002–2010 (n = 55).

Appendix 4.1 List of 84 waterbird species used in the correspondence analyses (CA). Species codes And the CA coordinates (scores) for Axes 1 and 2 are given for each species. The species codes refer to the labels used in the CA plots (Figures 4.12 and 4.13). Species marked with an asterisk (*) were used as supplementary columns in the analysis.

Common name	Species code	CA coordinates	
		Axis 1	Axis 2
African Black Duck	abd	0.303379	0.366455
African Black Oystercatcher	abo	0.886694	-0.40744
African Darter	ad	-0.0067	0.349558
African Fish-Eagle	afe	0.310852	-0.14816
African Jacana	aj	-0.71693	-0.64584
African Marsh-Harrier	amh	-0.08164	0.261772
African Purple Swamphen	aps	-0.30788	0.151213
African Sacred Ibis	asi	0.684271	0.349468
African Snipe	asn	-0.96582	-0.43437
African Spoonbill	as	0.221789	0.356978
Bank Cormorant	bcm	0.770795	1.833399
Black Crake	blc	-0.52208	-0.0222
Black Harrier	blh	-0.03445	0.757105
Black Stork	bls	0.76107	0.054929
Black-crowned Night-Heron	bnh	0.177219	0.490996
Black-headed Heron	bh	0.301239	0.571423
Black-necked Grebe	bg	-0.09306	0.12196
Blacksmith Lapwing	bl	0.188449	0.441437
Black-winged Stilt	bws	0.13823	0.350075
Blue Crane	bc	1.903786	-0.9578
Cape Cormorant	cc	0.517179	1.138804
Cape Shoveler	cs	-0.28383	0.121359
Cape Teal	ct	-0.01202	0.050747
Caspian Tern	cat	0.357002	0.02867
Cattle Egret	ce	-0.55015	-0.13951
Chestnut-banded Plover	cbp	-0.4615	-0.00299
Common Greenshank	cg	0.819947	-0.07239
Common Moorhen	cm	-0.74552	-0.20808
Common Ringed Plover	crp	1.943957	-2.00262
Common Sandpiper	csp	0.709201	0.103117
Common Tern*	cot	0.510315	0.218332
Common Whimbrel	cw	2.186517	-1.51888
Crowned Cormorant	crc	0.984186	1.711969
Curlew Sandpiper	cus	1.253561	-1.2185
Egyptian Goose	eg	0.289815	0.231169
Eurasian Curlew	ec	-0.11619	-0.30379
Giant Kingfisher	gk	0.703893	-0.16113
Glossy Ibis	gi	-0.55146	-0.13939
Great Crested Grebe	gcg	-0.05942	-0.05329
Great Egret	ge	-0.54089	-0.18769
Great White Pelican	gwp	0.885091	0.149599
Greater Flamingo	gfl	0.258345	-0.27951
Grey Plover	gh	2.591037	-2.47984
Grey Heron	gp	0.153021	0.339056
Grey-headed Gull	ghg	0.425127	0.63733
Hadeda Ibis	hi	0.316962	0.640416
Half-collared Kingfisher	hck	-0.4615	-0.00299
Hamerkop	hkp	-0.38671	-0.14207
Hartlaub's Gull	hg	0.282487	0.273477
Hottentot Teal	ht	-1.05217	-0.45883
Kelp Gull	kg	0.981259	0.406007
Kittlitz's Plover	kp	0.991134	-0.41646
Little Egret	le	0.533932	0.324137
Little Grebe	lg	-0.45412	-0.02309
Little Stint	ls	1.916477	-1.66323
Little Tern	lt	0.76107	0.054929
Maccoa Duck	md	-1.03693	-0.46733

Appendix 4.1 contd.

Common name	Species Code	CA coordinates	
		Axis 1	Axis 2
Malachite Kingfisher	mk	-0.29523	0.121559
Marsh Sandpiper	msp	-0.1156	-0.10024
Osprey	osp	0.058908	0.31866
Pied Avocet	pa	0.494393	0.24589
Pied Kingfisher	pk	0.503778	0.289975
Purple Heron	ph	-0.11552	0.375286
Red Knot	rkn	2.239221	-2.30751
Red-billed Teal	rtl	-0.19674	0.034469
Red-knobbed Coot	rc	-0.56231	-0.17795
Reed Cormorant	rcm	0.309139	0.680323
Ruddy Turnstone	rt	0.149784	0.025968
Ruff	rf	-0.56552	-0.15166
Sanderling	sdg	0.926915	-0.6158
Sandwich Tern*	sat	0.405460	0.423002
South African Shelduck	sas	0.468886	-0.16685
Southern Pochard	sp	-0.60426	-0.57431
Spur-winged Goose	swg	0.446996	-0.00326
Swift Tern	swt	0.6181	0.234049
Terek Sandpiper	tsp	-0.54931	-0.73935
Three-banded Plover	tp	0.79072	-0.51929
Water Thick-knee	wtk	0.438098	1.00388
White Stork	wst	2.852699	-2.6525
White-backed Duck	wbd	-0.95862	-0.49139
White-breasted Cormorant	wcm	0.192246	0.536314
White-fronted Plover	wp	0.151278	0.27697
White-winged Tern	wwt	0.308466	-0.46349
Wood Sandpiper	ws	-0.9045	-0.34487
Yellow-billed Duck	yd	-0.15081	0.245635
Yellow-billed Egret	ye	-0.37376	-0.12366

Chapter 5

Wetlands and waterbirds in the Western Cape, South Africa: associations and conservation importance

Abstract

The spatial context and importance of waterbirds and wetlands in the Western Cape were assessed using three methods – correspondence analysis, the Waterbird Conservation Value (WCV) score and Daily Energy Intake (DEI). There were strong waterbird-wetland associations between saline wetlands (estuaries and estuarine bays) and freshwater wetlands (lakes and waste water treatment works). Palearctic migrants were strongly associated with coastal sites while residents showed strong relationships with freshwater and/or brackish wetlands. Waterbird Conservation Value scores were higher in larger wetlands than in smaller wetlands and where large numbers of birds congregated. Fourteen species had populations that reached or surpassed 1% of their global populations during summer and winter at major wetlands in the Western Cape. Biomass and DEI values varied seasonally for most sites, with more energy being removed from wetlands during summer than winter which highlighted the importance of species using different sites at different times of the year. Site conservation status did not show strong associations with any waterbird groups. Overall, three sites, Strandfontein Waste Water Treatment Works, Langebaan Lagoon and Berg River Estuary were the most important sites in terms of numbers of birds, waterbird conservation value score and energy consumption. They contributed 49.7 % to the conservation value of all sites in the Western Cape and are critical localities for waterbird conservation in the region.

Plate 5.1 Waterbirds making use of a temporary flooded wetland area near Cape Town in August 2010. The white dots in the waterbody are Greater Flamingos. Photo: DM Harebottle.

Introduction

Chapter 2 described the development of the Waterbird Conservation Value (WCV) score and its application at flyway level. In Chapter 3, the WCV score was applied regionally at four representative wetlands within South Africa using visual analyses methods; the data on which the analyses were based were sourced from detailed site assessments in Appendices A–D. Chapter 4 looked at how the WCV score can be applied locally at site level and particularly at a site that has complex hydrological cycles, such as a temporary closed estuary. There is, however, a need to discuss the results of the five sites above in a greater regional context and to place these sites in the wider framework of wetland and waterbird conservation in the Western Cape.

Collins and Glen (1991), Bohninggaese et al. (1994), Flather and Sauer (1996) and Roshier et al. (2001) recognised that ecological processes that structure populations operate at broader landscape scales than those at which humans can visualise the landscape. Briggs and Lawler (1991) also found that Australian waterbirds interact with their habitat and visualise their environment at larger spatial scales than a single wetland or catchment

At site level, changes in species' populations are often attributed to overall demographic changes or spatial re-arrangement of individuals within it (Roshier et al. 2001). The latter infers that connections between wetland sites exist and that these inter-relationships contribute to both the spatial and temporal changes in populations, regardless of distances between sites. Although waterbird habitat may not be distributed evenly through the landscape (Roshier et al. 2001), characteristics at each wetland usually define the species composition and abundance; therefore similarities and associations between sites can be assessed.

It is therefore necessary to look at the broader network of wetlands in the winter rainfall region and assess their relative importance at a larger spatial scale. In this chapter I aim to determine waterbird associations between 30 key wetland sites in the Western Cape to identify any relationships between sites and then assess which sites are important. This was done based on three separate but related analyses:
(1) correspondence analysis that considers the composition, status and abundance of selected waterbirds at each site, (2) determining the Waterbird Conservation Value (WCV) score (see Chapter 2) of each site and assessing the conservation importance of these wetlands based on the WCV scores and (3) estimating and comparing the energy intake and biomass of waterbirds at each site. I also discuss the importance of inter-connectivity, landscape and climatic changes and local site factors in determining the relative significance of spatial distribution of wetlands in the winter rainfall region.

Methods

Correspondence analysis

To assess the spatial context of wetlands and waterbirds in the Western Cape Province, I applied correspondence analysis (CA) to the data matrix of mean species counts at a selection of 30 key wetlands; characteristics of each wetland are summarized in Appendix 1.5 (Chapter 1). Correspondence analysis would determine the association between waterbird composition and wetland sites (the data matrix) and display these in graphical two dimensional plots (Greenacre 1984, Underhill and Peisach 1985). The interpretation of the plots is described the Methods section in Chapter 4.

Correspondence analysis was performed using two matrices of mean species counts of waterbirds at sites, one for summer and one for winter. Counts of waterbirds at wetland sites were drawn from the Coordinated Waterbird Counts (CWAC) database at the Animal Demography Unit, University of Cape Town (unpubl. data). Sites which had two primary criteria were selected for inclusion in the analysis: (a) sites which supported, on average, a mean count of at least 2000 waterbirds during summer and/or winter surveys, or (b) sites which supported more than 50 species. The correspondence analysis and the resultant plots were carried out using program R (R Development Core Team 2012).

Waterbird Conservation Value (WCV) score

To place the conservation value of the five sites dealt with in this thesis within a broader landscape perspective (i.e. within the Western Cape Province), I compared each site's WCV score with the scores for the wetlands selected for the CA. The WCV score was based on the mean summer and winter abundance of each species. For computation and interpretation of the score refer to Methods in Chapter 2.

Biomass, Field Metabolic Rate and Daily Energy Intake

The total biomass of waterbirds at each priority wetland selected for the CA was estimated from the mean count of each species at each site in both summer and winter. Bird masses were taken from Hockey et al. (2005). The Field Metabolic Rate (FMR, kJ/day) was calculated for each species for each of the priority wetlands for summer and winter. FMRs were calculated using the same approach as in Underhill (1987) and Velásquez et al. (1991) the formula $10.9M^{0.640}$, where M is the body mass (g) of the species (Nagy 1987). An estimate of the Daily Energy Intake (DEI, kJ/day), including metabolized and non-metabolized energy, was obtained by correcting for Assimilation Efficiency (AE). Values of AE used were 58% for herbivores and 75% for invertebrate feeders and piscivores (Velásquez et al. 1991). Final assimilated DEI values were then summed across all species for each site to get an overall DEI value at each site. These values represent an estimate of total the amount of energy that the waterbird community extracts from each wetland.

Results and discussion

In this section it was convenient to discuss each of the results in turn, rather than attempt to separate them.

Waterbird and wetland relationships in the Western Cape

Results of the correspondence analyses are presented in Figures 5.1–5.8. When considering the type of wetland, it is evident that the estuaries and estuarine bays are well separated from the inland wetlands (e.g. farm dams, state impoundments and sewage works); the man-made sites are also quite distinct and form their own cluster in the bottom-right quadrant of the summer and winter plots (Figures 5.1a, b). The plots have a saline-freshwater gradient running from left to right such that sites plotted on the far left of the x-axis (e.g. De Mond Estuary, Langebaan Lagoon and Keurbooms Estuary) represent wetlands that are permanently or mostly saline while sites plotted on the far right of the x-axis are predominantly freshwater. The plots for the species during summer and winter confirm this with the marine/estuarine species (e.g. Palearctic and resident shorebirds and terns) being plotted more on the left and the freshwater species (kingfishers, waterfowl, grebes and waders) towards the right (Figures 5.6a, b). Sites plotted between these extremes would generally be classified as brackish wetlands and would have stronger or weaker affiliations to either saline or freshwater conditions depending on their location within the plot. Thus, for example, the Klein River, Diep River, Berg River and Groot Brak estuaries are plotted more towards the left hand side of the x-axis as they are more regularly open to the sea and therefore have stronger affinities to sites that are more saline or are permanently open to the sea (Figures 5.1a, b). They show a mixture of freshwater and coastal /marine species but do include species such as Wood Sandpiper and Common Sandpiper that are not entirely coastal or marine but which can tolerate more brackish conditions. However, they also include some coastal/marine species (Cape Cormorant, Common Whimbrel, African Black Oystercatcher, Common Greenshank and White-fronted Plover) that are absent or uncommon in freshwater wetlands.

In comparison, the Bot River Estuary, Wildevoëlvlei, Verlorenvlei, Wilderness Lakes and Zandvlei Estuary are open less frequently to the sea and therefore display stronger freshwater affinities, being plotted more towards the right side of the x-axis (Figures 5.1a, b). Zandvlei, Wildevoëlvlei, Verlorenvlei and Wilderness estuarine system in particular are estuaries that were grouped amongst the natural and man-made freshwater sites highlighting their freshwater dominance and sporadic (> 3 yrs) connection to the sea (Figure 5.4a, b). This results in their avifauna being dominated by species preferring freshwater, notably waterfowl (ducks, geese, coots and grebes).

Seasonally, there were differences between sites. For example, Langebaan Lagoon and Olifants River Mouth are more closely associated during summer than winter (Figures 5.1a, b). This is primarily due to similarities in their Palearctic shorebird communities over the austral summer. However, during winter, Langebaan Lagoon supports far greater numbers of Palearctic shorebirds than the Olifants River Mouth, notably Ruddy Turnstones, Sanderlings, Bar-tailed Godwits and Eurasian Curlews (Figures 5.6a, b, Figures 5.7a, b). These and other Palearctic shorebirds at the lagoon represent non-breeding, first-year birds and measure the annual breeding success from the previous season (Robertson 1981, Underhill 1987). Langebaan Lagoon is known to support the largest populations of over-wintering shorebirds in South Africa (Underhill 1987) and the results from this analysis provide evidence for this site's uniqueness in this regard during winter. A similar pattern was observed for the De Mond Estuary and Keurbooms Estuary; they had stronger association in winter than summer. Their summer waterbird populations comprised mainly Palearctic terns and shorebirds, but the De Mond Estuary supported larger numbers of these species. In winter, the Keurbooms Estuary supported more overwintering shorebirds but Cape Cormorant, White-breasted Cormorant and White-fronted Plover occurred in similar numbers at these sites.

A similar seasonal pattern was seen for the Wilderness and Swartvlei estuarine systems). However, compared with Langebaan Lagoon and Olifants River Mouth these sites are further removed from each other during winter. The plot shows that the Swartvlei estuarine system tends to become more saline during this period (Figure 5.1a, b). Whitfield et al. (1983) detailed how the Swartvlei opens more frequently during winter than the Wilderness estuarine system and how this changes the composition and abundance of the biodiversity in the system. Boshoff and Palmer (1991a, b, c) and Boshoff and Piper (1993) also provided evidence of a seasonal separation of the waterbird community at the Wilderness and Swartvlei estuarine systems.

The Berg River estuary lies separated and in similar positions in both the summer and winter plots (Figures 5.1a, b). This estuary is able to support large numbers of waterbirds (Table 2.5) and has high species richness, particularly during summer (Velasquez et al. 1991). One would anticipate that it would have stronger associations with other coastal sites such as Langebaan Lagoon and Olifants River Mouth, both of which support similar numbers and richness of waterbirds. The reason for the Berg River's separation from other coastal estuaries probably lies in its large size and greater habitat diversity; the site incorporates saline, brackish and freshwater habitats ranging from commercial saltpans, saltmarshes and sandbanks, to the river channel and adjacent floodplains (Velasquez et al. 1991). All these habitats are included in the waterbirds counts conducted as part of CWAC and are not restricted to the lower parts of the estuary. This habitat diversity allows the site to support a greater cosmopolitan avifauna rather than restricting it to species that preferentially prefer or utilise one or a couple of habitats.

Four sites – Rondevlei, Theewaterskloof, Zandvlei and Wildevoëlvlei – display particularly strong associations during summer but less so during winter (Figures 5.1a, b). Zandvlei and Wildevoëlvlei are classified as estuaries but are only intermittently open to the sea (Whitfield 2000). Theewaterskloof Dam is a large state dam while Rondevlei is a freshwater lake. There is a strong cormorant and waterfowl component in winter while in summer there were stronger links with kingfishers, rallids and waders (Figures 5.6a, b).

The four waste water treatment works (Strandfontein, Beaufort West, Macasser and Paarl) are generally closely associated during summer and winter, but have a stronger association during winter (Figures 5.1a, b). This is probably due to the high concentrations of waterfowl species that congregate at these sites after breeding in spring and early summer. These sites have permanent, deep water and are eutrophic throughout the year, ensuring a regular and constant supply of food (particularly macro-invertebrates). These factors probably aid in drawing these species to these sites during a period when food availability is lower in surrounding natural wetlands.

Radyn Dam and Droëvlei Dam, the two farms dams, are more closely associated during summer than during winter (Figures 5.1a, b). They are grouped together with other man-made sites such as Voëlvlei Dam, Strandfontein WWTW, Beaufort West WWTW and Rietvlei. These sites support species such as South African Shelduck, Maccoa Duck, Ruff, and White-winged Tern (Figures 5.6a, b and 5.7a, b).

If we consider the location of the wetlands in terms of being coastal or inland (Figures 5.2a, b) there was generally no strong associations and generally different wetlands types were well spread across these two spatial scales. Most sites were coastal wetlands, being either estuaries or coastal lakes. The six inland sites tended to be loosely grouped on the right hand side of axis one which confirmed their freshwater status, and with the exclusion of Theewaterskloof Dam, showed stronger affinities in summer than during winter (Figures 5.2a, b). If we consider just the estuarine sites, their waterbird communities reflected fairly strong summer and winter associations with the bioregion in which the estuary is located (Whitfield 2000). The cool temperate estuaries or estuarine bays – Olifants River, Verlorenvlei, Langebaan Lagoon, Berg River and Diep River – are loosely grouped together; however Verlorenvlei is well separated from the others (Figures 5.3a, b). This is most likely linked to the site being more of a coastal lake and having little estuarine affinity; the system rarely opens to the sea due to the mouth being blocked by a stony ridge and a dune barrier. The warm temperate sites showed stronger associations and interestingly the western estuaries (Zandvlei, Bot River and Klein River) show a closer relationship than the easterly located estuaries, particularly in winter. In summer, however, the Klein River Estuary was associated with the Breede River Estuary and Knysna Lagoon (Figures 5.3a, b).

Inundation patterns showed the strongest associations between sites, and more so in summer than in winter (Figures 5.4a, b). There were clear groupings between estuaries that were permanently open versus estuaries that are temporarily open, and between other sites with permanent water versus sites holding temporary water. Summer showed stronger affinities within groups especially for the permanently inundated sites; these sites would support higher concentrations of waterbirds during the dry season when temporary wetlands (such as Rocher Pan) would usually dry up. In winter, most of the non-estuarine wetlands would hold water making more sites available for waterbirds to use and hence the slighter weaker associations between groups as waterbird communities tended to diversify during this time. The permanently open estuaries showed little change from one season to the next and highlighted their specific role in supporting mainly marine and coastal waterbird communities. The temporarily open estuaries showed a little more variation but tended to show more similar waterbird associations during winter than summer. In winter, these estuaries are usually open to the sea due to increased run-off and therefore support similar waterbirds. The plot also elucidated the marine-freshwater gradient along Axis 1, which was discussed earlier in this section (Figures 5.4a, b).

In terms of conservation status at each site, there were no distinct clusters showing strong associations of sites with the same protection status during summer or winter (Figures 5.5a, b). Generally most sites were unprotected. The plot shows that protected sites covered an array of different wetland types ensuring that all major waterbird groups are afforded protection at least at some stage during their annual cycle. However, site conservation status probably does not play an over-riding factor in determining selection by waterbirds. Rather the type of inundation and associated site characteristics, typified by wetland type, were more important factors determining the composition and abundance of waterbirds at wetlands in the region.

For the species analyses, the species groups showed various associations (Figures 5.6 a, b, 5.7a, b, 5.8a, b). There was a distinct separation of coastal/estuarine species, on the left of the x-axis, from the freshwater species, to the right of the x-axis; there is a strong Palearctic migrant association with the coastal/saline species, while the freshwater species are primarily residents; some overlap does exist (Figures 5.6a, b). The Palearctic migrants mainly consist of shorebirds while the waterfowl, waders, kingfishers, cormorants and flamingos make up the bulk of the residents (Figures 5.7a, b). The freshwater Palearctic migrants such as Ruff, and White-winged Tern are grouped with the waterfowl and flamingos. Curlew Sandpiper and Little Stint are intermediate in their position on the plot which indicated that they were not confined to solely one habitat type. In winter the waterfowl show a tighter grouping as do the cormorants and kingfishers; most of the waterfowl tend to congregate in winter prior to breeding and are generally quite site specific in this regard (Figures 5.6a, b). Interestingly five species, South African Shelduck, Black-necked Grebe, Maccoa Duck, White-winged Tern and Ruff show a small grouping in the bottom right 'quadrant' of the plot. There are relatively few sites supporting these species and suggests that they are habitat specialists. These groupings mostly reflect the arrangement of sites during summer and winter with the estuarine sites (e.g. Langebaan Lagoon, De Mond Estuary) plotted on the extreme left and freshwater sites (Strandfontein WWTW, Rondevlei, Wilderness and Swartvlei estuarine systems) on the extreme right (see Figures 5.1a, b).

In terms of feeding guilds, the plots showed less clustering in summer and tighter grouping in winter (Figures 5.8a, b). Invertebrates were well spread throughout the plot, and in summer were dominated by the Palearctic shorebirds. Herbivores, were dominated by waterfowl and Lesser Flamingo, and showed a strong preference for the freshwater or brackish sites located on the right side of the x-axis. In this group, South African Shelduck and Lesser Flamingo showed a strong relationship both in summer and winter (Figures 5.8a, b) and suggests they prefer similar, select habitats. The piscivores showed some clustering particularly in summer; Cape Cormorant, Swift Tern, Common Tern, and Sandwich Tern formed a small 'coastal marine' cluster, while Reed Cormorant, White-breasted Cormorant, Grey Heron and Caspian Tern were grouped in a brackish cluster (Figure 5.8a). African Darter was separated from the Reed Cormorant and White-breasted Cormorant and showed a stronger association with Malachite Kingfisher, although in winter the darter and the cormorants had a stronger association (Figure 5.8b). This suggests that darters prefer more freshwater habitats all year round while the cormorants tend to show a shift from brackish to more freshwater sites during winter.

Waterbird Conservation Value (WCV) scores

Figures 5.9 and 5.10 show the variation of the WCV scores across all 30 sites for mean abundance during summer and winter respectively. The arrangements of sites along the x-axis in each figure from left to right is based on the first axes inertia of the CA so that they reflect the similarities presented in CA above.

All the open estuaries or estuarine bay sites are on the extreme left and primarily support the Palearctic shorebirds and other marine species, while the man-made, freshwater sites occur on the extreme right and support predominantly a freshwater avifauna (see Figures 5.1a, b and 5.2a, b). Sites situated between these two extremes usually comprise a mixture of brackish and freshwater components and therefore support a more mixed waterbird fauna. For example, Strandfontein WWTW lies approximately halfway on the x-axis. This site lies adjacent to the False Bay coastline and marine species such as Cape Cormorant, Kelp Gull and Swift Tern utilise the site for roosting and or breeding often in large numbers. The freshwater settling and oxidation ponds comprise by far the greatest open-water habitats and these support the significant number of waterfowl and other freshwater species present at the site (see below).

It is noticeable that the arrangements of sites on the x-axis varies slightly from summer to winter, but more importantly the composition of species at each site changes seasonally. Details of these changes and relevance are described and discussed in the following sections.

Three sites dominated both in summer and winter, all with WCV scores greater than 10: Strandfontein WWTW, Langebaan Lagoon and Berg River Estuary (Table 5.2). In summer, Strandfontein WWTW had the highest conservation value score (19.75) with Langebaan Lagoon (16.92) and Berg River Estuary (13.01) ranked second and third respectively. De Hoop Vlei and Bot River Estuary follow in fourth and fifth place with WCV scores of 7.27 and 6.72 respectively. Sites that rank sixth to 10th included, in order, Verlorenvlei (6.00), Wilderness estuarine system (5.68), Rietvlei (5.41), Rocher Pan (4.56) and Knysna Lagoon (3.99) (Table 5.2).

Strandfontein WWTW is dominated by seven species during summer, all of which have, on average, 1% or more of their global populations present at the site –

Hartlaub's Gull, Cape Shoveler, White-breasted Cormorant, Pied Avocet, Black-winged Stilt, Greater Flamingo and Kelp Gull (Figure 5.2, Table 5.2). The works supported the largest population of Hartlaub's Gull in the Western Cape at this time; Crawford (1997a) reported that the population had increased in the Cape Town metropole and that almost half the population was located in this region. Species that dominated Langebaan Lagoon included six shorebird species (Curlew Sandpiper, Grey Plover, Sanderling, Ruddy Turnstone and White-fronted Plover) and Hartlaub's Gull, while the four species that occurred at the Berg River that comprised 1% or more of their global populations included White-breasted Cormorant, Greater Flamingo, Hartlaub's Gull and Caspian Tern (Table 5.2).

During winter, Berg River estuary had the highest WCV score (15.16), with Langebaan Lagoon (13.83) and Strandfontein WWTW (11.68) ranked second and third respectively (Table 5.3). There is less variability in the WCV scores between the sites in winter compared with summer. De Hoop Vlei remains as fourth ranked wetland during winter with a score of 7.02, Wilderness estuarine system (6.44) moves up from seventh in summer to fifth in winter, while Verlorenvlei (5.30) remained ranked at number six for winter. The remaining four ranked sites in order were Swartvlei estuarine system (4.57), Bot River Estuary (4.53), Rietvlei (4.36) and Wadrif Saltpan (4.13) (Table 5.3).

The Berg River had a larger CV score during winter for resident species than during summer. This is due to the influx of three species which reach 1% levels during winter (Black-necked Grebe, Lesser Flamingo and Black-winged Stilt) (Table 5.3). Black-necked Grebes also reach 1% levels at Strandfontein WWTW in winter. Other species that reached 1% levels in summer are below this level (e.g. Cape Shoveler, Black-winged Stilt, Greater Flamingo and Hartlaub's Gull) or are absent from the site completely (e.g. Pied Avocet) in winter and this results in lower WCV scores during this period (Table 5.3). This reduces its overall conservation importance. Langebaan Lagoon in winter shows fairly large declines in the numbers of Greater Flamingo with populations falling below the 1% level to 0.85, (from 1.46 in summer), while Hartlaub's Gull increases its 1% level from 1.65 in summer to 2.56 in winter. Coupled with the absence of the majority of the 1% shorebird populations (Curlew Sandpiper, Grey Plover and Sanderling) in winter, the lagoon's WCV score decreases from 16.92 to13.83. Nevertheless it remains ranked as the second most important wetland during winter.

Fourteen species had populations that reached or surpassed 1% of their global populations during summer and winter at major wetlands in the Western Cape (Tables 5.2 and 5.3). Of these only the Ruddy Turnstone is a Palearctic migrant;

populations of this species were concentrated at Langebaan Lagoon. The remaining species showed a mixed composition and comprised three waterfowl species (Cape Shoveler, Yellow-billed Duck and Great Crested Grebe), two species of cormorants (White-breasted Cormorant and Cape Cormorant), two species of shorebirds (African Black Oystercatcher and White-fronted Plover), two species of waders (Greater Flamingo and Black-winged Stilt), two species of gulls (Hartlaub's Gull and Kelp Gull) and two species of terns (Caspian Tern and Swift Tern). The Cape Cormorant and African Black Oystercatcher are both Red Data species (Barnes 2000). Cape Shoveler dominated at four sites: Swartvlei estuarine system, Strandfontein WWTW, De Hoop Vlei and Wilderness estuarine system, all located along the southern coast of the Western Cape. Yellow-billed Duck seems to prefer De Hoop Vlei and Wilderness estuarine system (Table 5.3). Regionally, Greater Flamingos are more abundant in winter; in summer their overall WCV score was 5.37 while in winter it was 8.40; i.e. an increase of three times the global 1% threshold level for this species and substantiates the post-breeding dispersal of this species after summer from their breeding localities in Botswana and Namibia (Williams and Velasquez 1997). Swift Tern dominated in winter with Rocher Pan supporting the bulk of the winter population (WCV score = 1.66); no sites supported 1% or more of the species global population in summer, although some sites (Keurbooms Estuary, Langebaan Lagoon and Strandfontein WWTW) did meet 0.5% levels (Table 5.5). The Rocher Pan influx in winter possibly represents post-breeding dispersal northward away from localities in the Western Cape where it breeds in late-summer (Crawford 1997b).

Black-winged Stilts showed summer dominance at Strandfontein WWTW (WCV score = 1.07) and the Berg River Estuary (0.94) (Table 5.2). In winter, their abundance declined at Strandfontein WWTW to below a WCV score of 0.50% but increased at Bot River Estuary to 1.65. Paarl WWTW showed a winter influx from a WCV score in summer of 0.33 to 0.83 in winter (Table 5.3), the site having sub-regional significance for this species. These results suggest that this species tends to prefer sewage treatment works and is not partial to coastal versus inland sites. Langebaan Lagoon supports by far the greatest White-fronted Plover population in the Western Cape. It is the only site that supports more than 1% of its global population during summer and winter (Tables 5.2 and 5.3). The only other site to support any reasonable populations was Olifants River Mouth, particularly in winter when its WCV index was 0.29, the highest of any other site (Table 5.3).

Five species – Pied Avocet, South African Shelduck, Egyptian Goose, Great White Pelican and Grey Plover – had populations that, on average, reached 1% or 0.5%

levels only in summer (Table 5.2). Again, only a single Palearctic species, Grey Plover, was listed amongst these and most of its Western Cape population is concentrated at Langebaan Lagoon during this period (Table 5.2). The South African Shelduck and Egyptian Goose congregate in early summer to moult (Maclean 1997a, b.) and their large numbers at Radyn Dam and Voëlvlei Dam confirm their preference for large, deep waterbodies to complete their annual moult. Voëlvlei Dam is an historical moulting site for Egyptian Goose (Siegfried 1967) which continues to be favoured by the geese. Pied Avocet is primarily nomadic moving around in response to rainfall and wetland inundation (Tree 1997). Their summer peaks at selected sites, particularly Strandfontein, Verlorenvlei, and Rietvlei highlights their occurrence at shallow, permanent waterbodies during the dry summer period when temporary wetlands dry out in the surrounding landscape. Numbers of Great White Pelican increased in summer, especially along the west coast of the Western Cape. Verlorenvlei is the only site that supports more than 0.5% of the global population during this period (Table 5.2) and is possibly due to sections of the lake drying up providing shallow water in which fish become concentrated. Up to 650 pairs breed on Dassen Island (33°35'S 18°04'E) from October–January and they undertake the 250-km round trip to Verlorenvlei daily during this period to feed chicks (de Ponte Machado 2010). The Great White Pelican is the only Red Data species in this group (Barnes 2000)

The following species only reached threshold levels during winter at respective sites: Black-necked Grebe, Red-knobbed Coot, Maccoa Duck, Lesser Flamingo, Little Grebe and Southern Pochard (Table 5.3). These species' winter dominance probably indicates partial seasonal movement within the region after summer. Black-necked Grebes are known to move to coastal localities once their summer rainfall inland breeding localities have dried up in winter (Boshoff et al. 1991a, Dean and Underhill 1997). Globally important numbers occurred at Berg River Estuary and Strandfontein WWTW (Table 5.3). The highest proportion of Red-knobbed Coots occurred at coastal localities particularly Bot River Estuary, De Hoop Vlei and Swartvlei estuary system (Table 5.3). These sites offer large open-water habitats with predominantly still water and emergent and aquatic vegetation, characteristics which are preferred by Red-knobbed Coots. It is possible that their large concentrations at the above three sites relates to post-breeding flocking (Taylor 1997) from temporarily inundated sites during the wet season, and historically these three sites have been selected for this annual activity. Lesser Flamingo, a near-threatened species (Barnes 2000), may be more mobile than Greater Flamingo and prefer selected localities which could explain their higher winter numbers compared with Greater Flamingo. Movements of Maccoa Duck are poorly understood but bird atlas models (Maclean 1997c) suggest that influxes occur in the southwestern parts of the Western Cape during times when water-levels are at their peak, confirming the high winter populations of the species in this study. Two artificial wetlands, Strandfontein WWTW and Droëvlei, supported by far the largest concentration and together they accounted for 1.13% of the global population (Table 5.3). Strandfontein WWTW holds, on average, the majority of Southern Pochard (WCV score = 0.64). Coupled with the WCV scores from the other sites in the Western Cape that supported the species (Tables 5.2 and 7.3), the overall WCV score totals 1.32 and placed the conservation value of Southern Pochard more in a regional context than at site level. Maclean and Harrison (1997) describe a July–December peak of Southern Pochard into the Western Cape and suggest possible movements between summer rainfall and winter rainfall areas. This study confirms the seasonal occurrence of this species in the Western Cape, particularly in the winter rainfall region.

Daily Energy Intake (DEI)

Figure 5.12 shows the Daily Energy Intake (DEI) across all 30 wetland sites for summer and winter. A total of 17 sites show no or little variation in summer and winter DEI values. More energy is extracted from nine sites in summer, while only four sites show greater winter than summer DEI values (Langebaan Lagoon, Berg River Estuary, Wilderness estuarine system and Bot River Estuary).

Most energy is extracted from Strandfontein WWTW, Wadrif Saltpan and De Hoop Vlei in summer, while the top three sites in winter are Berg River Estuary, Langebaan Lagoon and De Hoop Vlei (Figure 5.12, Table 5.1). It is interesting that De Hoop Vlei has similar DEI values for summer and winter (Table 5.1). Decreases in Egyptian Goose, Cape Shoveler and Southern Pochard and Greater Flamingo in winter is compensated by increases in Little Grebe, Red-knobbed Coot, Lesser Flamingo and Spur-winged Goose which results in energy consumption being equal during both seasons. In contrast, Langebaan Lagoon's waterbird biomass is doubled in winter (Table 5.1). This is mainly due to a 6-fold increase of Greater Flamingos which then increases the DEI of the waterbird community in the lagoon. The abundance of larger, heavier birds, such as flamingos, has greater impact on the system than many smaller bodied, lighter birds like Curlew Sandpipers and Little Stints which dominate the lagoon during summer.

Wadrif Saltpan displays the greatest variation between summer and winter DEI; the site goes from a summer DEI value of 12266 MJ/day to 2327 MJ/day in winter, a decrease of 9 939 MJ/day (Figure 5.12, Table 5.1). Other sites showing large summer-winter differences in energy consumption included Verlorenvlei (a decrease of 4986 MJ/day in winter), Voëlvlei Dam (4889 MJ/day), Theewaterskloof Dam (4427 MJ/day) and Strandfontein WWTW (4175 MJ/day) (Table 5.3).

What role does DEI play in terms of waterbird ecology? Williams (2003) described how the energy flow through a waterbird community aids in nutrient mixing and recycling which effectively determines the health of a wetland system to support a suite of waterbirds. He goes on to state, that, for example, a large flock of Flamingos feeding and defecating in a wetland are able to constantly mix nutrients in the water which stimulates plant and macro-invertebrate productivity. Large flocks of waterbirds moving around in the landscape and utilising different wetlands therefore aid in keeping nutrients in wetland systems well mixed which in turn provide good feeding and breeding opportunities. Sites that lose a large proportion of their waterbird communities from one season to the next are probably more subject to water quality issues than sites where there is a constant arrival of waterbirds, particularly from different feeding guilds. The Red-knobbed Coot at the Bot River Estuary are estimated to remove and recycle as much as 10% of the submerged macrophytes annually through feeding and nest-building (Stewart and Bally 1985), a function that would not be cost-effective if removal of *Potamogeton* and *Ruppia* beds had to done mechanically.

Consequently, sites such as Voëlvlei Dam which supports large numbers of Egyptian Goose during summer results in very high DEI values but overall the site has little conservation value. Similarly sites like Droëvlei Dam and Theewaterskloof Dam where large concentrations of certain species (notably ducks and geese which gather to moult after breeding) also have skewed seasonal DEI values (Table 5.3). Thus, some sites become important in supplying vital nutrients at a certain time of year or provide suitable habitat requirements in a species' annual cycle but they have little conservation value from an abundance perspective. Are these sites less significant or important than those sites which support conservation worthy species? I would argue not, emphasizing that all sites play some or other role in a regional context, whether they function as stop-over sites, breeding sites or year-round refuges for waterbirds.

Regional importance of wetlands for waterbirds in the Western Cape

The above results show, in terms of WCV scores, Strandfontein WWTW, Langebaan lagoon and the Berg River estuary are the most important sites in the Western Cape; seasonally Strandfontein WWTW is the most important site in summer and the Berg River estuary in winter (Figure 5.11). In context, these three sites contribute 49.7 % to the conservation value of all sites in the Western Cape to waterbirds. This highlights not only the regional importance of the Western Cape for waterbirds but also the global significance of the region in meeting global population thresholds.

With large numbers of Palearctic shorebirds present during summer and Langebaan Lagoon and Berg River Estuary are well-known shorebird localities (Underhill 1987, Velásquez et al.1991). However, resident species are the main contributors to Strandfontein WWTW's high conservation value, and not Palearctic species. The main species driving this are, in descending order of mean abundance, Cape Cormorant, Kelp Gull, Hartlaub's Gull and Greater Flamingo. However based on the 1% thresholds, and translated in the WCV score, Hartlaub's Gull (3.7%), Pied Avocet (3.4%), Cape Shoveler (2.23%), Kelp Gull (1.65%) and Greater Flamingo (1.5%) are considered of greater conservation importance (Table 7.2).

Strandfontein WWTW is also well known breeding locality for many resident waterbirds (Ashkenazi 2001) which most likely contributed to the high DEI value (13 376 MJ/day) during summer. Thus waterbirds have a large impact on the food resources available at the works. The reason for this is that Strandfontein supported larger numbers of heavier species (waterfowl, cormorants and gulls, all of which breed at the works) compared with the smaller bodied shorebirds which dominated at Langebaan Lagoon; so although Langebaan Lagoon supported double the numbers of birds, on average, in summer, in terms of biomass the birds had less impact on the wetland. The Berg River estuary is primarily used as a feeding site by both resident and Palearctic shorebirds during summer and most likely explains its lower DEI value compared with Langebaan Lagoon and Strandfontein WWTW.

Based on this and the fact that species richness is at its maximum in summer, I propose that Strandfontein WWTW be considered as the most important waterbird site in the Western Cape. The interesting aspect of this is that the works is only *c.* 400 ha in size, and is located within the Cape Town metropole (Figure 1.5, Chapter 1). This is highlighted when compared with the larger natural systems of Langebaan Lagoon (*c.* 4500 ha) and Berg River Estuary (c. 7300 ha) (Figure 5.11). This places responsibility on the provincial and local authorities to ensure its long-term survival as an important waterbird locality in the Western Cape. It is certainly eligible for Ramsar status with the site supporting 1% of the global population of seven waterbird species. Currently the site is unprotected but the local authority (City of Cape Town) is proposing official local protection for the site through a revision of its protected area status policy within the Cape Town metropole (C. Dorse pers. comm.). Once the site is afforded formal conservation status, application to Ramsar can be undertaken. Although Ramsar status does not afford any legal protection of the site, it will elevate the site to being of global importance and not just at local or regional levels. Globally, waste-water treatment works are well known waterbird sites and usually offer a mosaic of favourable habitats to waterbirds (Fuller and Glue 1980). Eutrophic conditions year-round also provide a fairly constant food supply aiding utilisation by waterbirds as prime foraging and breeding localities (Kalejta-Summers et al. 2000, Ashkenazi 2001, Appendix A).

It is also interesting that it is not always species that dominate numerically at a site that have high 1% levels. Reed Cormorant and Egyptian Goose are, for example, species that occur in large numbers at numerous sites but rarely reach 1% levels. What this means is that these species make small contributions to the WCV score at a site even though in a South African context they occur relatively abundantly. Global thresholds are set based on population estimates for subspecies or bio-geographical populations which are subject to change every four years when population estimates are revised (Wetlands International 2006). Thus, species that have a small WCV scores in a particular year may, due to taxonomic or bio-geographic revisions of the global population, contribute more to a WCV score further down the line. WCV scores could therefore change on a four-yearly cycle. This would have implication for wetland site managers and conservation authorities who manage the sites. Other species which show similar patterns are Curlew Sandpiper.

In contrast, Pied Avocet, Cape Shoveler and Caspian Tern are examples of species that make greater contributions from the 1% perspective rather than having large populations. In these cases global populations are relatively small due to restricted ranges and/or intrinsic population limiting factors (Baker 2006). Thus, numbers of these species at a site, although they do not seem excessively high, regularly reach global thresholds due to the threshold level being set relatively low as a result of global populations being small. These species therefore are of conservation importance at site level.

It is clear from this study that threshold levels and the WCV score and not solely numerical abundance label a site as being of conservation value. Historically, the latter together with rare or threatened waterbirds were considered as the primary motivating factor for identifying sites of conservation importance (Sjizz 1972). However, with the introduction of the 1% species threshold levels in 1972 more emphasis was placed on the contribution a local population was making to the overall population to determine its conservation value (Sjizz 1972). It should be borne in mind that the conservation value of a site may change seasonally in response to changing conditions and waterbird annual cycles and movement patterns. This highlights the need for regular seasonal long-term monitoring of waterbirds at wetlands in order to identify temporal changes in abundance and associated 1% threshold levels. This would aid conservation managers in determining appropriate management action at the site.

The application of the 1% criterion has enabled over 1900 wetlands globally to be designated as wetlands of international importance (Ramsar 2010). In Europe, and much of the northern hemisphere, wetlands are more permanent and waterbirds more constant and predictable in number, compared with southern Africa. For the latter, wetlands are largely ephemeral in nature and waterbird numbers can fluctuate widely between seasons. Hence, the 0.5% criterion was introduced to designate IBAs at a sub-regional level (Barnes 1998, Chapter 3) and assign some importance to sites. Since many sub-Saharan waterbird species populations remain unknown or constitute large region-wide estimates, sites that support important numbers of species at a regional (provincial) level will never reach these thresholds and will never be recognised as important at a global scale. They do, however, have significance at provincial and/or national level and it is my opinion that they should be recognised as making important contributions. The conservation value of a site, through application of the Waterbird Conservation Value score as used in this thesis, provides a tool for rapidly assessing the overall importance of species based on numerical abundance. This tool can easily be applied and extended and applied to long-term waterbird datasets in South Africa to assess sites on national basis. The development of a national '1%' or equivalent threshold should also be considered in order to assess national importance of sites, and not just at a sub-regional or global level.

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Table 5.1 Summary of summer and winter abundance, biomass, Field Metabolic Rate (FMR), Daily Energy Intake (DEI) and Waterbird Conservation Value (WCV) score at 30 wetlands in the Western Cape. Sites ranked based on WCV score for summer and winter.

		Summer								Winter					
Rank	Site code	Mean no. birds	Mean biomass (kg)	FMR (MJ/day)	DEI (MJ/day)	No. spp at 1% level	WCV score	Rank	Site code	Mean no. birds	Mean biomass (kg)	FMR (MJ/day)	DEI (MJ/day)	No. spp at 1% level	WCV score
1	st	12806	12641	10147	13736	7	19.75	1	bg	9652	12048	9188	13217	5	15.16
2	lb	27524	5974	7221	9174	6	16.92	2	lb	11315	14484	9948	12840	4	13.83
3	bg	10298	8794	6656	8903	4	13.01	3	st	7643	9032	7122	9561	4	11.68
4	DH	5710	7940	7006	11600	1	7.27	4	DH	5203	7583	6866	11508	1	7.02
5	BT	4558	4952	3887	5829	2	6.72	5	wt	6514	4777	4696	7755	1	6.44
6	ve	3828	6561	4768	8152	1	6.00	6	ve	1916	3305	2191	3166	1	5.30
7	wt	5946	4709	4517	7493	2	5.68	7	ws	8101	6000	5937	10076	0	4.57
8	rv	4419	4348	3300	5247	1	5.41	8	BT	5265	4693	4166	6690	0	4.53
9	RP	3197	3151	2442	3512	1	4.56	9	rv	2407	2716	2085	3100	0	4.36
10	kn	4550	1845	1939	2658	0	3.99	10	wa	2548	2235	1741	2327	1	4.13
11	ws	2124	1827	1477	2055	1	3.92	11	kn	2670	2183	2010	2640	1	3.61
12	wa	5070	9933	7024	12266	0	3.23	12	PA	1650	1299	1123	1673	0	3.22
13	vv	3756	5881	3972	6169	1	2.92	13	RP	1534	1761	1368	1980	0	3.07
14	kl	2401	1781	1701	2757	0	2.63	14	kb	936	700	662	844	0	2.41
15	PA	2821	2148	1798	2785	0	2.59	15	ol	1020	828	703	968	0	2.14
16	rd	2430	3182	2342	3697	1	2.47	16	wv	1421	950	929	1445	0	1.93
17	kb	1163	724	709	916	0	1.95	17	kl	2018	1497	1483	2513	0	1.78
18	th	5581	3996	4027	6812	0	1.85	18	jk	832	987	788	1088	0	1.27
19	ol	1267	746	539	686	0	1.80	19	zv	1010	955	833	1350	0	1.15
20	jk	1340	746	738	1036	0	1.67	20	th	1355	1924	1472	2385	0	1.05
21	DV	1935	1267	1120	1775	0	1.53	21	DV	791	705	607	983	0	1.00
22	zv	1287	1225	1076	1818	0	1.42	22	dm	229	282	191	248	0	0.94
23	wv	858	535	544	847	0	1.18	23	dp	410	311	284	388	0	0.77
24	br	901	665	596	821	0	1.10	24	br	486	576	461	664	0	0.75
25	dm	1038	232	295	373	0	1.09	25	rd	364	382	312	493	0	0.66
26	rn	726	1009	724	955	0	0.95	26	mc	381	239	245	367	0	0.58
27	dp	455	229	232	305	0	0.82	27	rn	406	503	399	528	0	0.42
28	mc	565	257	276	413	0	0.73	28	gb	145	133	116	151	0	0.38
29	gb	312	186	191	247	0	0.65	29	bw	392	323	294	416	0	0.34
30	bw	593	355	337	462	0	0.41	30	vv	571	1025	736	1280	0	0.29

Table 5.2 Summer Waterbird Conservation Value (WCV) scores and species making major contributions to the score for 30 wetland sites in the Western Cape. Values based on mean abundance. Values in bold represent species that reached 1% threshold levels and those in italics 0.5% threshold levels. Species whose WCV score was zero is represented with a dash (–).

		Species																						
Rank	**Site**	Cape Shoveler	Yellow-billed Duck	South African Shelduck	Egyptian Goose	Great Crested Grebe	White-bresated Cormorant	Cape Cormorant	Great White Pelican	Black-winged Stilt	Pied Avocet	Greater Flamingo	African Black Oystercatcher	White Fronted Plover	Red-billed Teal	Grey Plover	Sanderling	Curlew Sandpiper	Kelp Gull	Hartlaub's Gull	Swift tern	Caspian Tern	Other	**WCV score**
1	Strandfontein WWTW	**2.23**	0.20	0.03	0.10	0.10	**1.55**	*0.99*	0.27	**1.07**	**3.44**	**1.46**	0.19	–	–	–	–	0.02	**1.65**	**3.60**	**0.57**	0.26	2.01	19.75
2	Langebaan Lagoon	–	0.07	0.04	0.01	–	0.14	0.10	0.19	0.14	0.24	*0.73*	0.40	**1.21**	**1.68**	**1.34**	**1.09**	**5.06**	0.39	**1.65**	**0.58**	**0.69**	1.17	16.92
3	Berg River Estuary	0.09	0.25	0.27	–	0.09	**1.59**	0.45	0.39	*0.94*	0.37	**1.16**	0.03	0.04	–	0.05	0.01	*0.86*	0.43	**1.39**	0.36	**2.43**	1.82	13.01
4	De Hoop Vlei	**2.11**	*0.65*	0.14	0.22	*0.59*	0.48	–	0.11	0.36	0.12	0.28	–	0.02	–	–	0.01	0.10	0.02	–	0.01	0.35	1.70	7.27
5	Bot River Estuary	0.31	0.30	–	0.05	**1.21**	0.49	–	0.17	0.21	0.01	*0.60*	0.01	0.08	–	–	–	0.01	0.27	0.70	0.31	**1.24**	0.75	6.72
6	Verlorenvlei	0.17	0.09	*0.52*	0.32	0.45	*0.75*	–	*0.92*	0.21	**1.10**	0.01	–	–	–	–	–	0.06	0.08	0.29	–	**0.61**	0.42	6.00
7	Wilderness Estuarine system	**1.59**	*0.77*	–	0.08	**1.45**	0.38	–	–	0.16	0.02	0.01	–	–	–	–	–	–	0.03	–	–	0.09	1.08	5.68
8	Rietvlei	0.35	0.12	0.01	0.32	0.04	0.44	–	0.28	0.26	*0.92*	0.05	0.17	–	–	–	0.03	0.09	0.07	**1.49**	0.01	0.25	0.51	5.41
9	Rocher Pan	*0.85*	0.05	0.06	0.01	0.01	**1.18**	–	0.02	0.49	0.20	*0.52*	0.08	0.01	–	–	–	0.13	0.10	0.15	0.02	0.04	0.63	4.56
10	Knysna Lagoon	0.27	0.14	–	0.06	–	0.14	0.02	–	0.27	0.12	–	*0.96*	0.01	–	0.14	–	0.60	0.50	–	0.24	0.13	0.39	3.99
11	Swartvlei Estuarine system	**1.56**	0.26	–	0.01	*0.51*	0.20	–	–	0.12	0.02	–	0.03	0.01	–	–	–	0.02	0.04	–	–	**0.50**	0.65	3.92
12	Wadrif Saltpan	0.32	0.08	*0.50*	0.02	0.01	0.01	–	0.01	0.33	*0.52*	0.32	–	0.10	–	–	0.01	0.08	–	0.03	0.04	0.01	0.85	3.23
13	Voëlvlei Dam	–	–	*0.94*	**1.26**	0.01	0.06	–	–	–	–	–	–	–	–	–	–	–	–	0.02	–	0.45	0.16	2.92
14	Kleinriviersvlei	0.24	0.10	–	0.01	0.04	0.27	–	–	0.07	–	0.08	*0.59*	0.09	–	–	–	0.01	0.08	0.33	0.08	0.40	0.25	2.63
15	Paarl WWTW	0.17	0.03	–	0.13	0.02	0.23	–	0.03	0.33	0.05	0.04	–	–	–	–	–	–	–	*0.83*	–	–	0.73	2.59
16	Radyn Dam	0.07	0.07	**1.16**	0.21	0.06	0.08	–	0.10	0.05	0.07	0.01	–	–	–	–	–	0.01	–	–	–	–	0.59	2.47
17	Keurbooms River Estuary	–	–	–	0.01	–	0.12	0.01	–	–	–	–	0.29	0.09	–	0.05	–	0.04	0.49	–	**0.71**	0.02	0.12	1.95
18	Theewaterskloof Dam	0.03	0.15	–	0.75	0.01	0.45	–	–	–	–	–	–	–	–	–	–	–	0.03	0.02	–	0.01	0.41	1.85
19	Olifants River Mouth	–	–	0.02	–	–	0.20	–	0.23	0.01	0.20	0.01	0.05	0.18	–	0.02	0.03	0.16	0.04	0.12	0.30	0.10	0.14	1.80
20	Jakkalsvlei	0.25	0.01	0.03	0.01	0.01	0.03	–	–	0.09	–	0.05	0.01	–	–	–	–	–	0.25	0.27	0.33	0.02	0.30	1.67
21	Droëvlei Dam	0.21	0.10	0.02	0.08	0.06	0.02	–	0.03	0.08	0.14	0.03	–	–	–	–	–	0.03	–	–	–	–	0.73	1.53
22	Zandvlei Estuary	0.02	0.01	–	0.07	0.28	0.05	–	0.01	0.05	0.13	–	–	–	–	–	–	–	0.02	0.26	–	0.38	0.15	1.42
23	Wildevoëlvlei	0.14	0.07	–	0.01	0.03	0.07	–	–	0.11	0.13	–	–	–	–	–	–	–	–	0.26	–	0.01	0.35	1.18
24	Breede River Estuary	–	0.04	0.15	0.02	–	0.10	–	–	0.01	0.03	–	0.08	0.06	–	0.02	–	0.01	0.29	–	0.04	0.06	0.17	1.10
25	De Mond Estuary	–	–	–	–	–	0.21	–	–	–	–	–	0.09	0.15	–	0.01	0.03	0.04	0.04	–	0.04	0.29	0.19	1.09
26	Rondevlei	0.04	0.03	0.01	0.01	0.08	0.11	–	0.17	0.01	–	–	–	–	–	–	–	–	–	0.08	–	0.18	0.23	0.95
27	Diep River Estuary	0.01	0.01	–	–	–	0.13	–	–	0.01	–	–	0.01	–	–	–	–	0.01	0.07	0.34	0.08	0.08	0.07	0.82
28	Macasser WWTW	0.05	0.05	–	0.01	–	0.01	–	–	0.10	–	–	0.01	–	–	–	–	–	–	0.43	0.02	0.01	0.05	0.73
29	Great Brak River Estuary	0.01	0.02	–	–	–	0.04	–	–	0.01	–	–	0.15	–	–	–	–	–	0.04	–	0.31	0.04	0.03	0.65
30	Beaufort West WWTW	0.06	0.01	0.04	–	–	0.01	–	–	0.07	0.03	–	–	–	–	–	–	–	–	–	–	–	0.19	0.42
	Total	**1.15**	**3.68**	**3.94**	**3.78**	**5.06**	**9.54**	**1.57**	**2.93**	**5.56**	**7.86**	**5.36**	**3.15**	**2.05**	**1.68**	**1.63**	**1.21**	**7.34**	**4.93**	**12.26**	**4.05**	**8.65**	**16.84**	

Table 5.3 Winter Waterbird Conservation Value (WCV) scores and species making major contributions to the score for 30 wetland sites in the Western Cape. Values based on mean abundance. Values in bold represent species that reached 1% threshold levels and those in italics 0.5% threshold levels. Species whose CV score was zero is represented with a dash (–).

		Species																					
Rank	Site	Cape Shoveler	Yellow-billed Duck	Southern Pochard	Maccoa Duck	Black-necked Grebe	Great Crested Grebe	Little Grebe	White-breasted Cormorant	Cape Cormorant	Red-knobbed Coot	Black-winged Stilt	Greater Flamingo	Lesser Flamingo	African Black Oystercatcher	White-fronted Plover	Ruddy Turnstone	Hartlaub's Gull	Kelp Gull	Swift Tern	Caspian Tern	Other	WCV score
1	Berg River Estuary	0.28	0.13	0.02	0.13	**2.64**	0.03	0.03	*0.70*	*0.66*	0.25	**1.65**	**1.53**	**1.52**	0.07	0.14	–	**1.45**	*0.71*	*0.61*	*0.94*	1.68	**15.16**
2	Langebaan Lagoon	0.02	0.03	–	–	–	–	–	0.25	0.04	–	0.42	**4.19**	*0.54*	*0.72*	**1.04**	*0.51*	**2.56**	**0.52**	0.07	**1.27**	1.65	**13.83**
3	Strandfontein WWTW	*0.74*	0.06	*0.64*	*0.81*	**2.02**	0.02	0.48	**1.02**	**1.06**	0.08	0.49	*0.85*	–	0.19	–	–	*0.90*	**1.33**	0.05	0.02	0.90	**11.68**
4	De Hoop Vlei	**1.49**	*0.53*	0.15	*0.50*	0.44	*0.51*	0.16	*0.71*	–	*0.76*	0.31	0.18	0.19	–	0.04	–	–	0.04	–	0.47	0.54	**7.02**
5	Wilderness Estuary	0.43	0.44	0.29	*0.91*	0.34	**1.55**	*0.60*	*0.82*	0.04	*0.52*	0.05	–	–	–	–	–	–	0.03	–	0.03	0.39	**6.44**
6	Verlorenvlei	0.12	0.06	0.01	0.01	–	0.57	0.04	**2.09**	–	0.05	0.19	0.07	0.02	0.01	–	–	0.07	0.05	0.01	*0.93*	1.01	**5.30**
7	Swartvlei Estuarine system	*0.88*	0.29	0.01	–	–	*0.50*	0.41	*0.59*	0.01	*0.83*	0.28	0.07	–	0.03	–	–	–	0.05	–	0.33	0.28	**4.57**
8	Bot River Estuary	0.34	0.30	0.04	0.01	0.14	*0.70*	0.12	–	0.02	0.40	0.09	0.25	–	–	0.12	–	0.44	0.26	0.23	*0.53*	0.53	**4.53**
9	Rietvlei	*0.52*	0.20	0.01	–	–	0.13	0.02	*0.58*	–	0.07	0.47	0.08	0.01	0.15	–	–	**1.00**	0.22	0.01	0.20	0.69	**4.36**
10	Wadrif Saltpan	0.09	–	–	0.01	0.26	–	0.01	0.01	–	–	0.19	*0.57*	0.24	0.07	0.07	–	*0.54*	0.01	**1.66**	0.01	0.39	**4.13**
11	Knysna Lagoon	0.16	0.11	–	–	–	–	0.01	0.36	0.14	–	0.42	–	–	*1.02*	0.04	–	–	*0.65*	0.03	0.13	0.55	**3.61**
12	Paarl WWTW	0.12	0.03	0.02	0.13	0.13	0.01	0.16	0.38	–	0.01	*0.83*	0.02	0.05	–	–	–	*0.99*	–	–	–	0.32	**3.22**
13	Rocher Pan	0.45	0.03	–	0.05	0.40	0.02	0.02	0.48	–	0.06	0.25	0.31	0.02	0.19	0.01	–	0.27	0.07	0.15	0.16	0.12	**3.07**
14	Keurbooms River Estuary	–	–	–	–	0.04	–	0.05	0.21	0.01	–	0.02	–	–	0.29	0.13	–	–	0.43	*0.99*	0.11	0.12	**2.41**
15	Olifants River Mouth	0.02	0.01	–	–	–	–	–	0.20	–	0.01	0.06	0.07	0.10	0.08	0.29	–	0.28	0.22	0.41	0.13	0.26	**2.14**
16	Wildevoëlvlei	0.20	0.06	0.03	0.12	0.07	0.04	0.23	0.29	–	0.07	0.13	–	–	–	–	–	0.42	–	–	0.09	0.19	**1.93**
17	Kleinriviersvlei	0.15	0.08	–	–	–	0.01	–	0.22	–	0.21	0.04	–	–	*0.50*	0.06	–	0.14	0.05	0.10	0.15	0.07	**1.78**
18	Jakkalsvlei	0.06	0.01	–	0.02	0.12	–	0.01	0.02	–	0.02	0.06	0.14	0.07	0.03	–	–	0.10	*0.51*	0.05	–	0.04	**1.27**
19	Zandvlei Estuary	0.03	0.01	–	–	–	0.26	0.03	0.18	0.01	0.06	0.06	–	–	–	–	–	0.18	0.02	–	0.08	0.22	**1.15**
20	Theewaterskloof Dam	0.01	0.23	0.03	–	–	0.02	0.01	0.26	–	0.01	–	–	–	–	–	–	–	0.03	–	–	0.44	**1.05**
21	Droëvlei Dam	0.15	0.06	0.01	0.32	0.07	0.02	0.04	0.02	–	0.03	0.05	0.04	0.08	–	–	–	–	–	–	–	0.11	**1.00**
22	De Mond Estuary	0.01	–	–	–	–	–	–	0.23	0.01	–	–	–	–	0.07	0.17	–	–	0.04	0.03	0.25	0.13	**0.94**
23	Diep River Estuary	0.04	0.02	–	–	–	–	–	0.12	–	–	0.03	–	–	0.01	–	–	0.25	0.14	–	0.05	0.09	**0.77**
24	Breede River Estuary	0.02	0.07	–	–	–	–	–	0.21	0.03	–	0.01	–	–	0.06	0.05	–	–	0.09	0.07	0.05	0.11	**0.75**
25	Radyn Dam	0.05	0.02	–	0.27	0.09	0.01	0.02	0.03	–	0.01	0.03	0.01	–	–	–	–	–	–	–	–	0.10	**0.66**
26	Macasser WWTW	0.04	0.06	0.04	–	–	–	0.01	–	–	0.01	0.12	–	–	–	–	–	0.22	0.04	–	–	0.05	**0.58**
27	Rondevlei	0.03	0.02	0.01	–	–	0.03	0.01	0.08	–	–	–	0.01	–	–	–	–	0.03	0.01	–	0.05	0.14	**0.42**
28	Great Brak River Estuary	0.01	0.01	–	–	–	0.01	0.01	0.10	–	–	0.04	–	–	0.04	0.01	–	–	0.04	0.09	–	0.02	**0.38**
29	Beaufort West WWTW	0.05	0.04	0.01	0.02	0.02	–	0.02	–	–	0.01	0.04	–	–	–	–	–	–	–	–	–	0.14	**0.34**
30	Voëlvlei Dam	–	–	–	–	–	–	–	0.04	–	0.01	0.01	–	–	–	–	–	–	0.01	–	0.05	0.18	**0.29**
	Total	**6.51**	**2.91**	**1.32**	**3.31**	**6.78**	**4.44**	**2.50**	**10.18**	**2.03**	**3.48**	**6.34**	**8.39**	**2.84**	**3.53**	**2.17**	**0.51**	**9.84**	**5.57**	**4.56**	**6.03**	**11.46**	

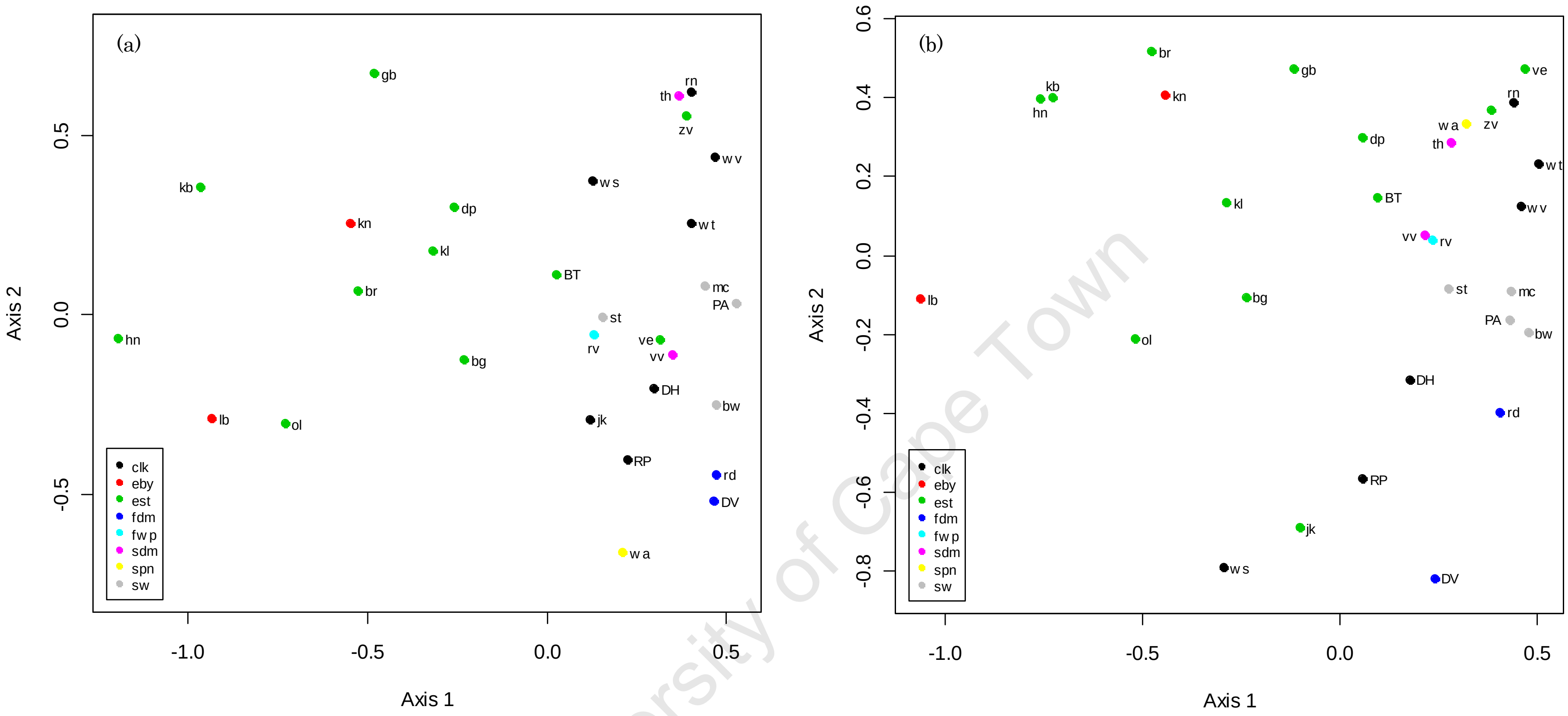


Figure 5.1 Plots of 30 wetland sites in the Western Cape during (a) summer and (b) winter based on correspondence analysis and categorised according to wetland type. The plots represent the first principal plane of the correspondence analysis. For (a) the horizontal axis represents the first principal dimension and accounts for 27.1% of the inertia, and the vertical axis represents the second principal dimension and accounts for 19.2% of the inertia. For (b) the horizontal axis accounts for 26.2% of the inertia, and the vertical axis accounts for 17.0% of the inertia. Legend codes: clk = coastal lake, eby = estuarine bay, est = estuary, fdm = farm dam, fwp = freshwater pan, sdm = state dam, spn = saltpan and sw = sewage works, For site labels refer to Table 5.1.

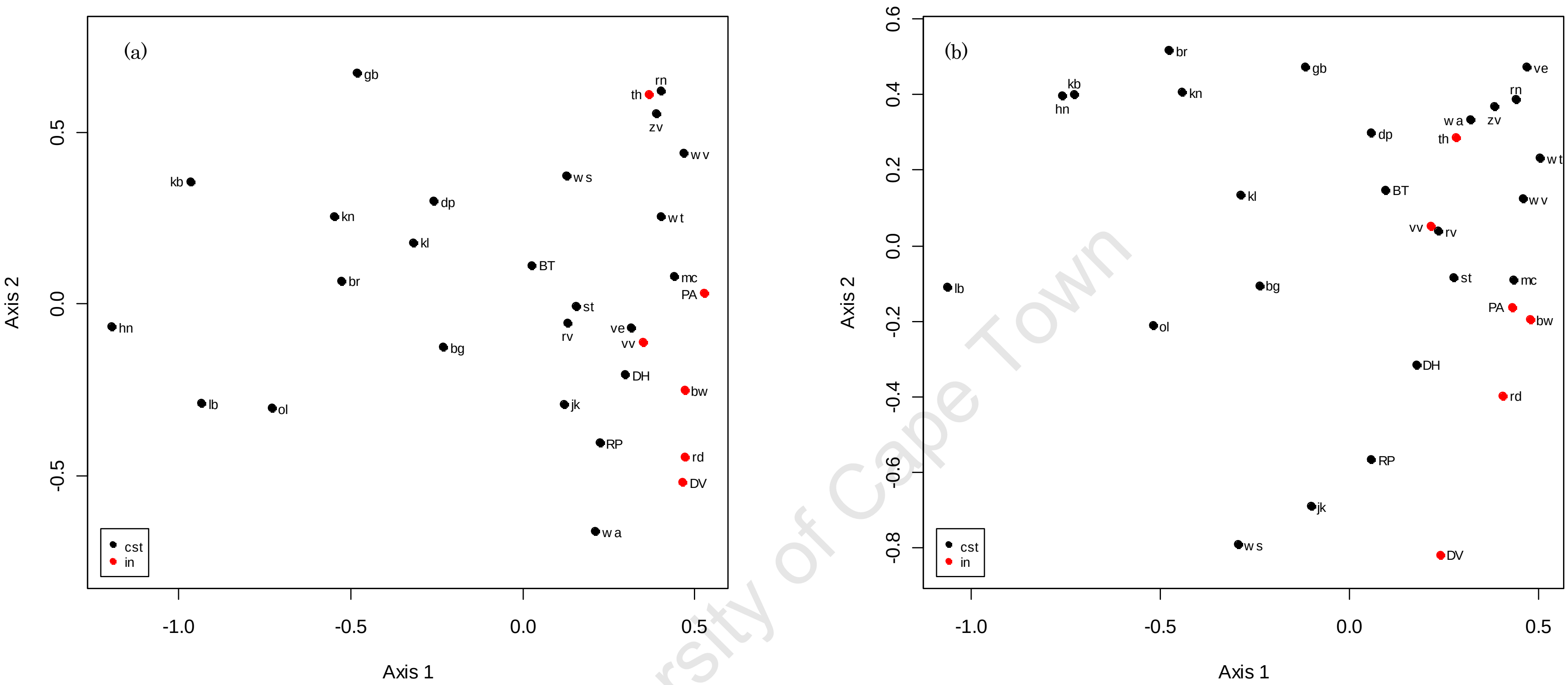


Figure 5.2 Plots of 30 wetland sites in the Western Cape during (a) summer and (b) winter based on correspondence analysis and categorised according to wetland location. The plots represent the first principal plane of the correspondence analysis. For (a) the horizontal axis represents the first principal dimension and accounts for 27.1% of the inertia, and the vertical axis represents the second principal dimension and accounts for 19.2% of the inertia. For (b) the horizontal axis accounts for 26.2% of the inertia, and the vertical axis accounts for 17.0% of the inertia. Legend labels: cst = coastal, in = inland. For site labels refer to Table 5.3.

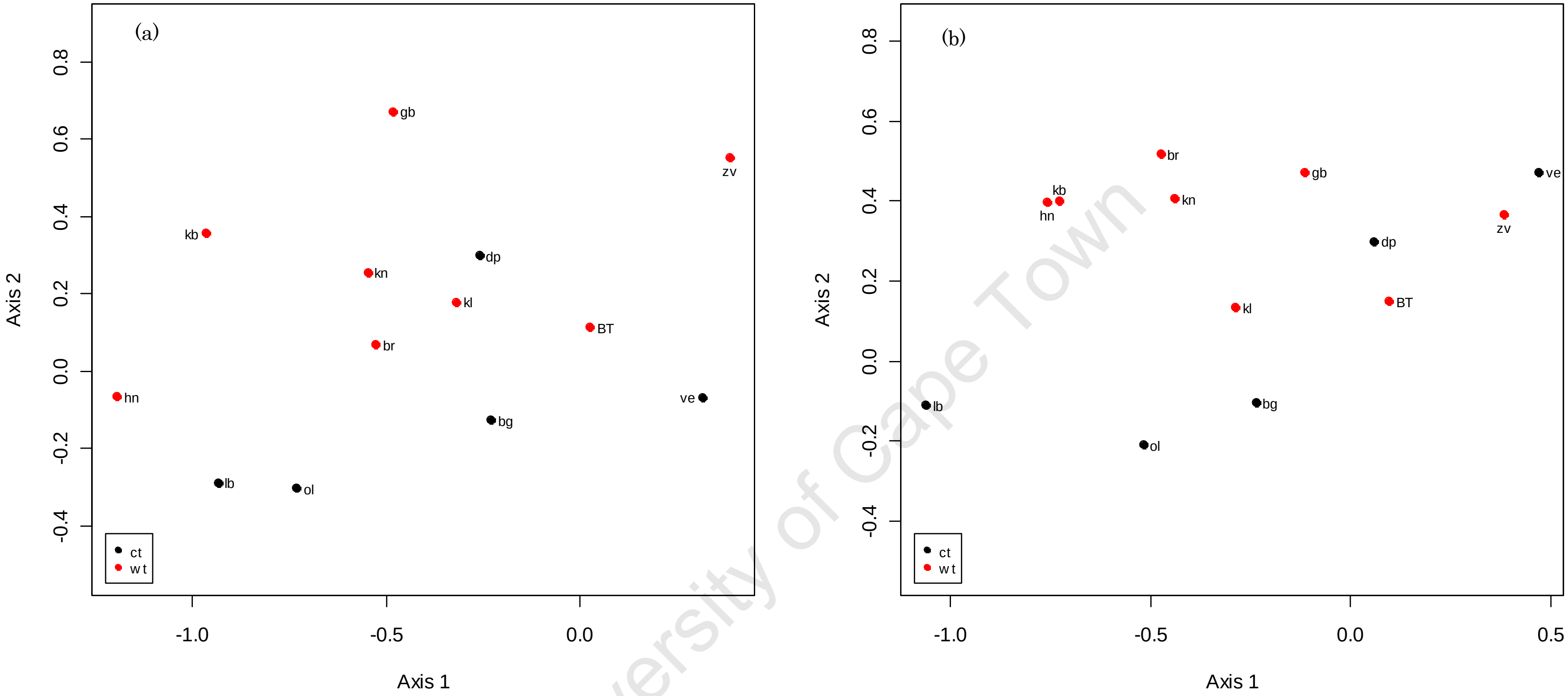


Figure 5.3 Plots of 30 wetland sites in the Western Cape during (a) summer and (b) winter based on correspondence analysis and categorised according to estuarine bio-region (Whitfield 2000). The plots represent the first principal plane of the correspondence analysis. For (a) the horizontal axis represents the first principal dimension and accounts for 27.1% of the inertia, and the vertical axis represents the second principal dimension and accounts for 19.2% of the inertia. For (b) the horizontal axis accounts for 26.2% of the inertia, and the vertical axis accounts for 17.0% of the inertia. Legend labels; ct = cool temperate, wt = warm temperate. For site labels refer to Table 5.3.

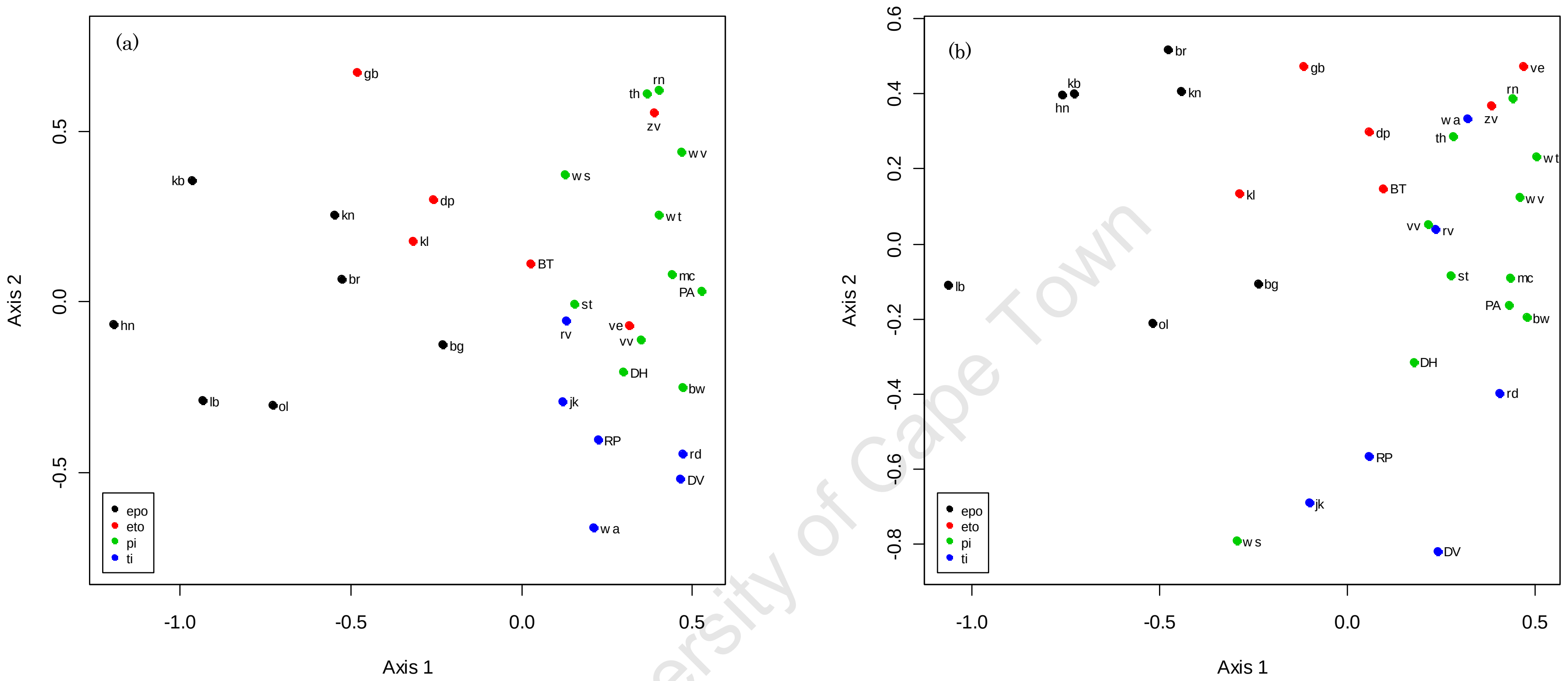


Figure 5.4 Plots of 30 wetland sites in the Western Cape during (a) summer and (b) winter based on correspondence analysis and categorised according to inundation pattern (see Whitfield 2000). The plots represent the first principal plane of the correspondence analysis. For (a) the horizontal axis represents the first principal dimension and accounts for 27.1% of the inertia, and the vertical axis represents the second principal dimension and accounts for 19.2% of the inertia. For (b) the horizontal axis accounts for 26.2% of the inertia, and the vertical axis accounts for 17.0% of the inertia. Legend labels: epo = estuary, permanently open, eto = estuary, temporarily open, pi = permanently inundated and ti = temporarily inundated. For site labels refer to Table 5.3.

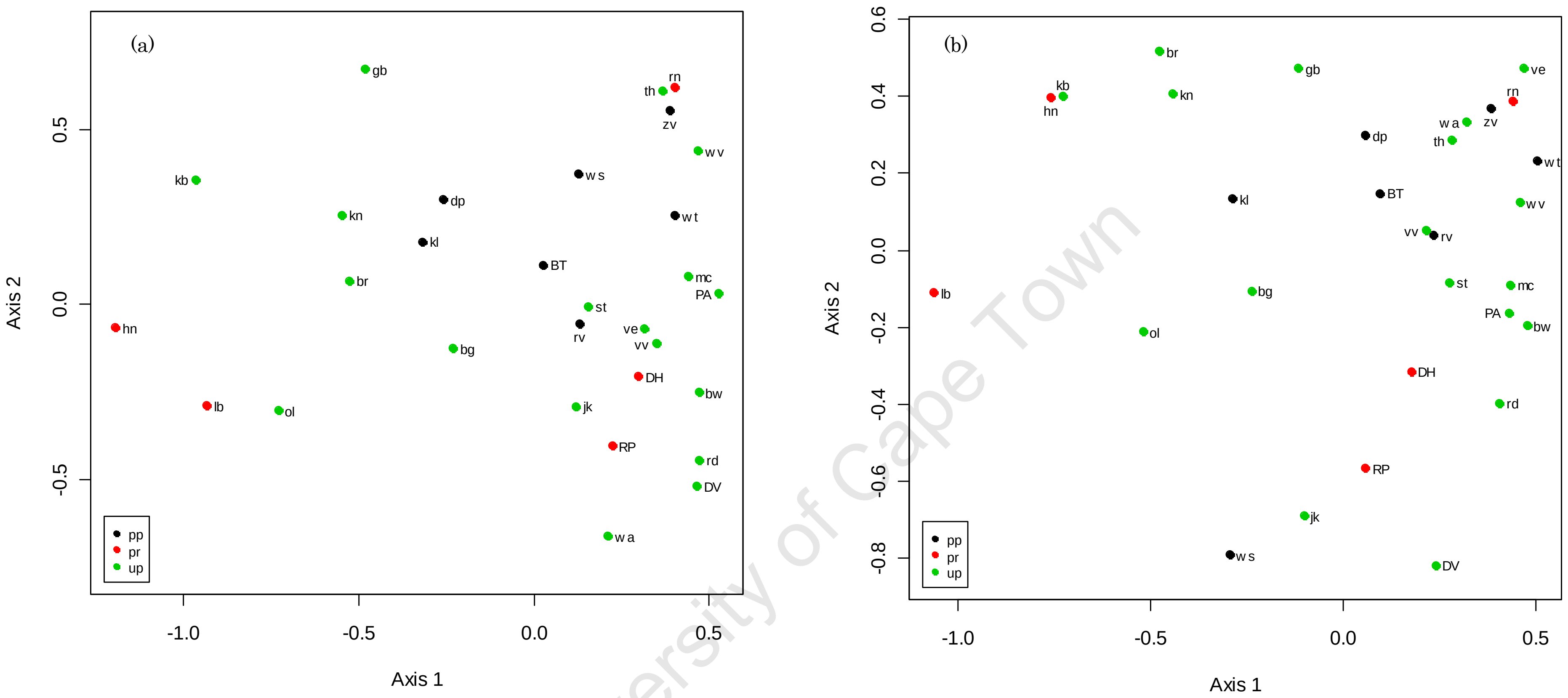


Figure 5.5 Plots of 30 wetland sites in the Western Cape during (a) summer and (b) winter based on correspondence analysis and categorised according to conservation status of each site. The plots represent the first principal plane of the correspondence analysis. For (a) the horizontal axis represents the first principal dimension and accounts for 27.1% of the inertia, and the vertical axis represents the second principal dimension and accounts for 19.2% of the inertia. For (b) the horizontal axis accounts for 26.2% of the inertia, and the vertical axis accounts for 17.0% of the inertia. Legend labels: pp = partly protected, pr = protected, up = unprotected. For site labels refer to Table 5.3.

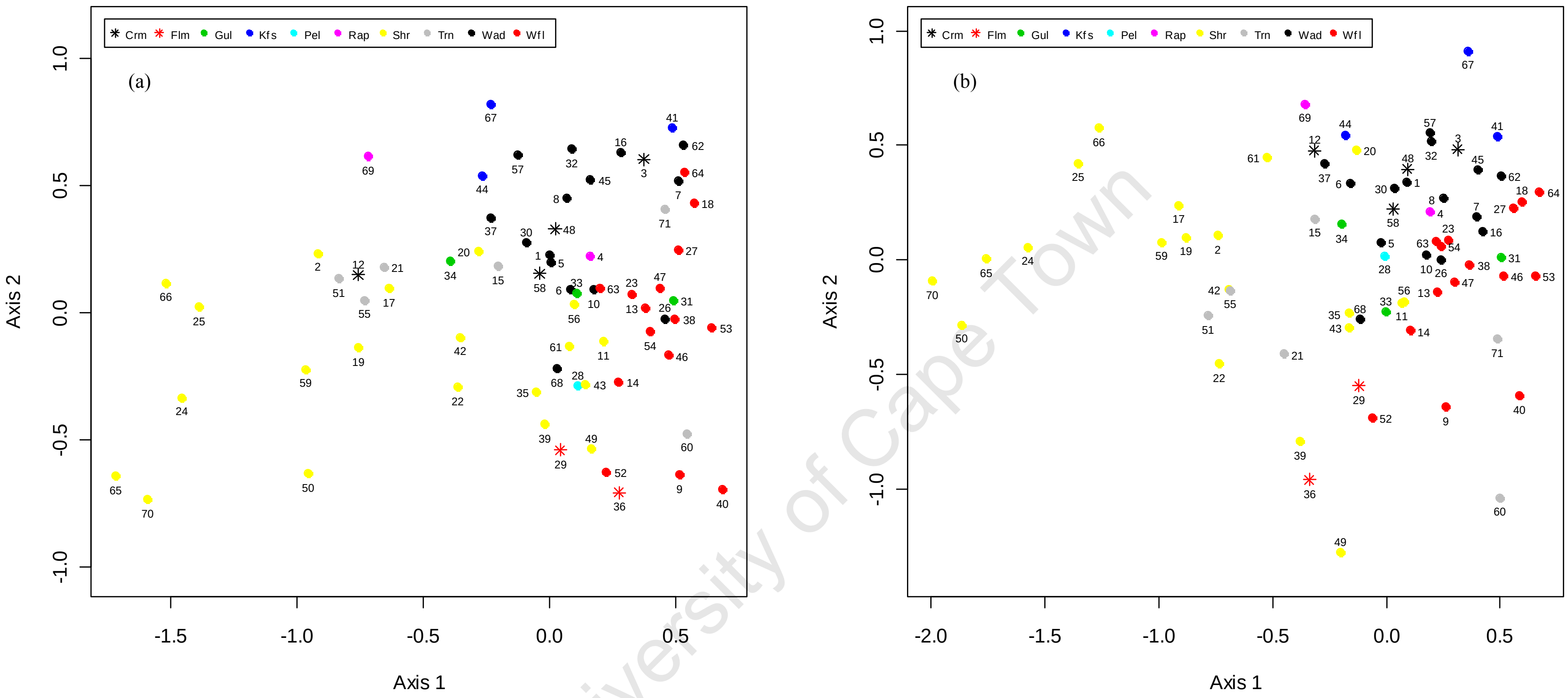


Figure 5.6 Plots of 71 waterbird species from 30 sites in the Western Cape during (a) summer and (b) winter based on correspondence analysis and categorised according to species group. The plots represent the first principal plane of the correspondence analysis. For (a) the horizontal axis represents the first principal dimension and accounts for 30.3% of the inertia, and the vertical axis represents the second principal dimension and accounts for 14.6% of the inertia. For (b) the horizontal axis accounts for 25.3% of the inertia, and the vertical axis accounts for 15.4% of the inertia. Legend labels: Crm = Cormorants and darter, Flm = Flamingo, Gul = Gull, Kfs = Kingfisher, Pel = Pelican, Rap = Raptor, Shr = Shorebird, Trn = Tern, Wad = Wader, Wfl = Waterfowl. For site labels refer to Appendix 5.1.

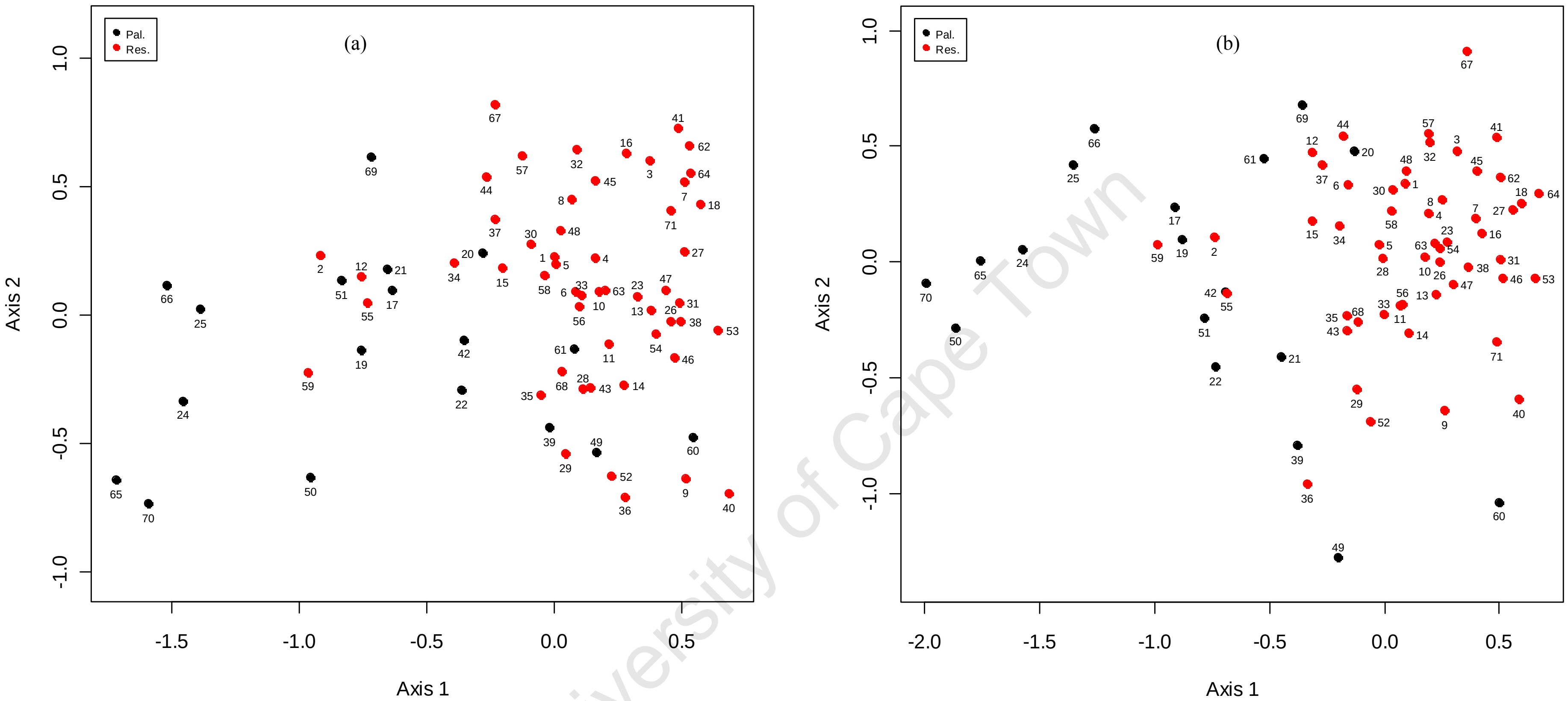


Figure 5.7 Plots of 71 waterbird species from 30 sites in the Western Cape during (a) summer and (b) winter based on correspondence analysis and categorised according to occurrence status. The plots represent the first principal plane of the correspondence analysis. For (a) the horizontal axis represents the first principal dimension and accounts for 30.3% of the inertia, and the vertical axis represents the second principal dimension and accounts for 14.6% of the inertia. For (b) the horizontal axis accounts for 25.3% of the inertia, and the vertical axis accounts for 15.4% of the inertia. Legend labels: Pal. = Palearctic migrants, Res. = residents. For site labels refer to Appendix 5.1.

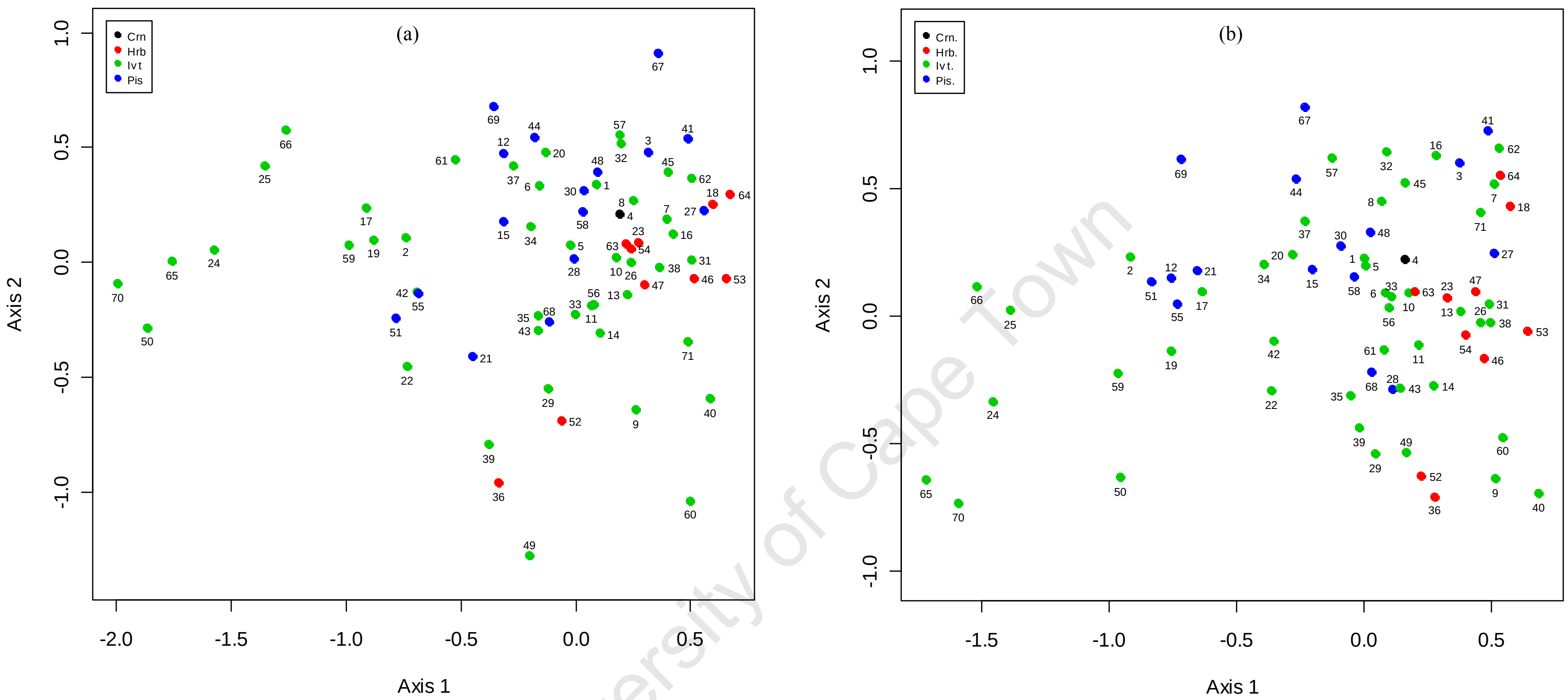


Figure 5.8 Plots of 71 waterbird species from 30 sites in the Western Cape during (a) summer and (b) winter based on correspondence analysis and categorised according to feeding guild. The plots represent the first principal plane of the correspondence analysis. For (a) the horizontal axis represents the first principal dimension and accounts for 30.3% of the inertia, and the vertical axis represents the second principal dimension and accounts for 14.6% of the inertia. For (b) the horizontal axis accounts for 25.3% of the inertia, and the vertical axis accounts for 15.4% of the inertia. Legend labels: Crn = Carnivore, Hrb. = Herbivore, Ivt. = Invertebrate feeder, Pis. = Piscivore. For site labels refer to Appendix 5.1.

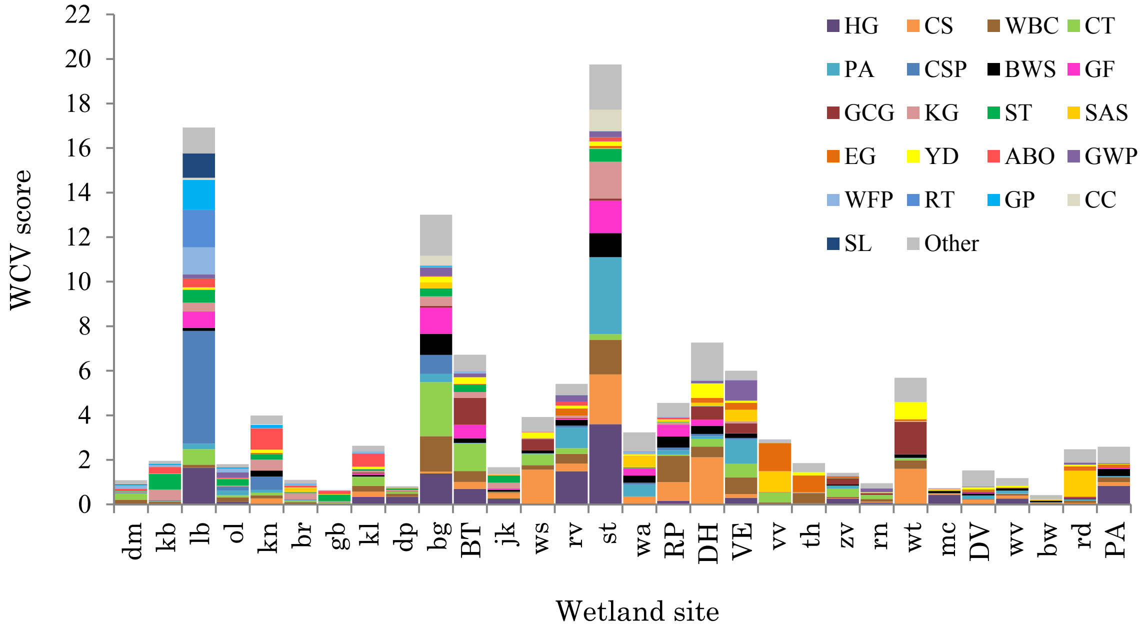


Figure 5.9 Waterbird Conservation Value (WCV) scores for 30 wetland sites in the Western Cape during summer. Species compositions based on Table 5.2. Results based on the mean abundance of each species at each site and sorted in ascending order (left to right) of the inertia on the first axis of the correspondence analysis. For wetland site abbreviations see Table 5.3, and for legend species abbreviations see Table 5.3.

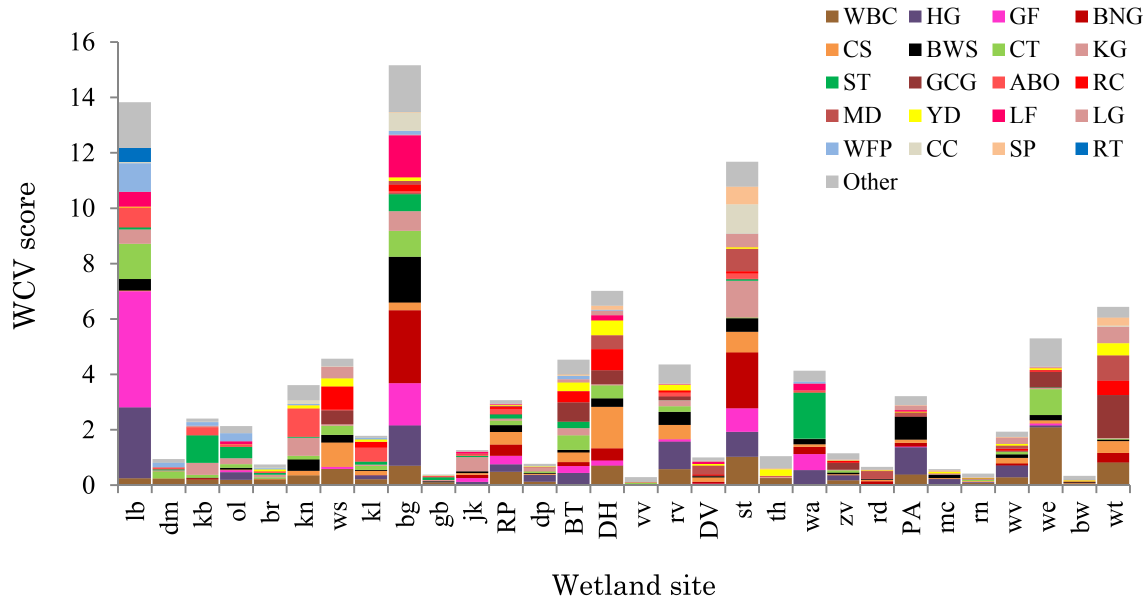


Figure 5.10 Waterbird Conservation Value (WCV) scores for 30 wetland sites in the Western Cape during winter. Species compositions based on Table 5.2. Results based on the mean abundance of each species at each site and sorted in ascending order (left to right) of the inertia on the first axis of the correspondence analysis. For wetland site abbreviations see Table 5.3 and for legend species abbreviations see Table 5.3.

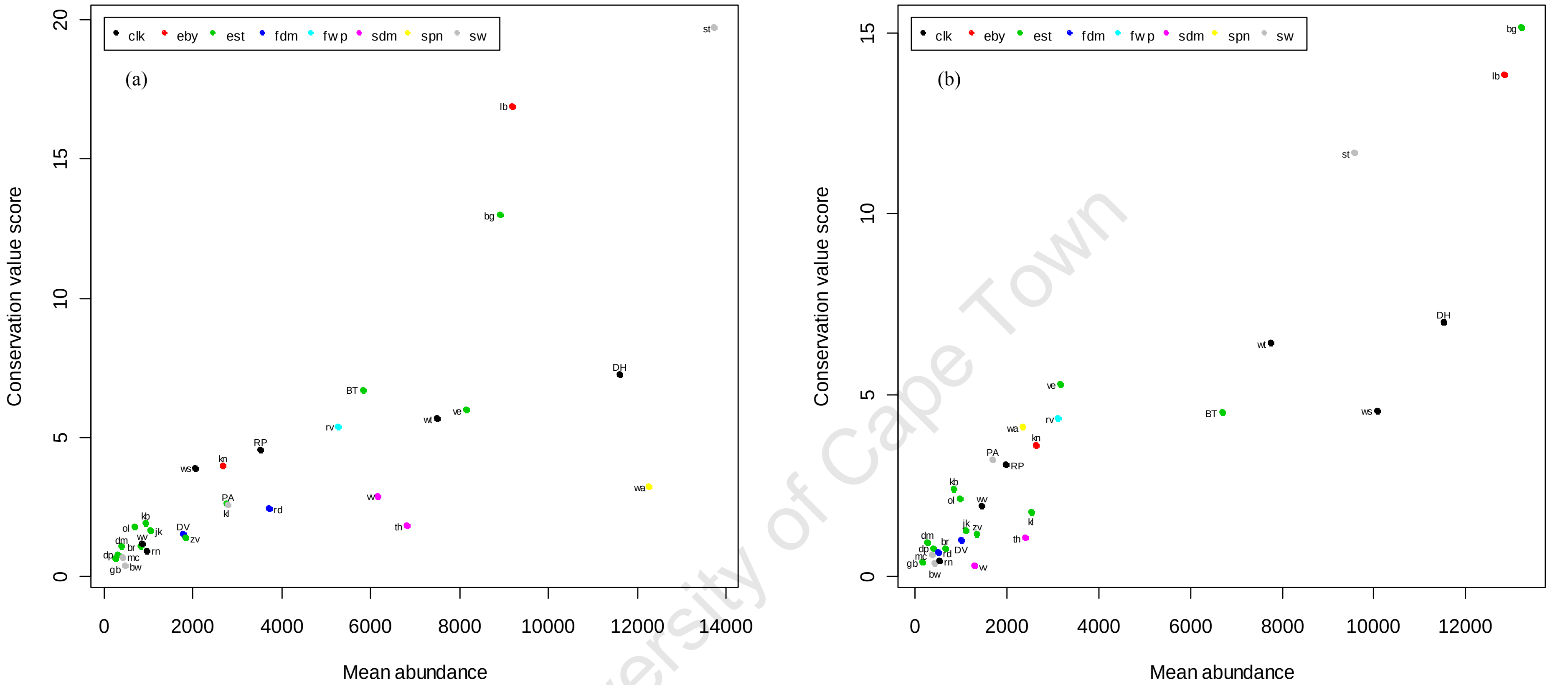


Figure 5.11 Plot of 30 wetland sites in the Western Cape in (a) summer and (b) winter showing the relationship between abundance and the conservation value score. Legend codes: clk = coastal lake, eby = estuarine bay, est = estuary, fdm = farm dam, fwp = freshwater pan, sdm = state dam, spn = saltpan and sw = sewage works. For site labels refer to Table 5.1.

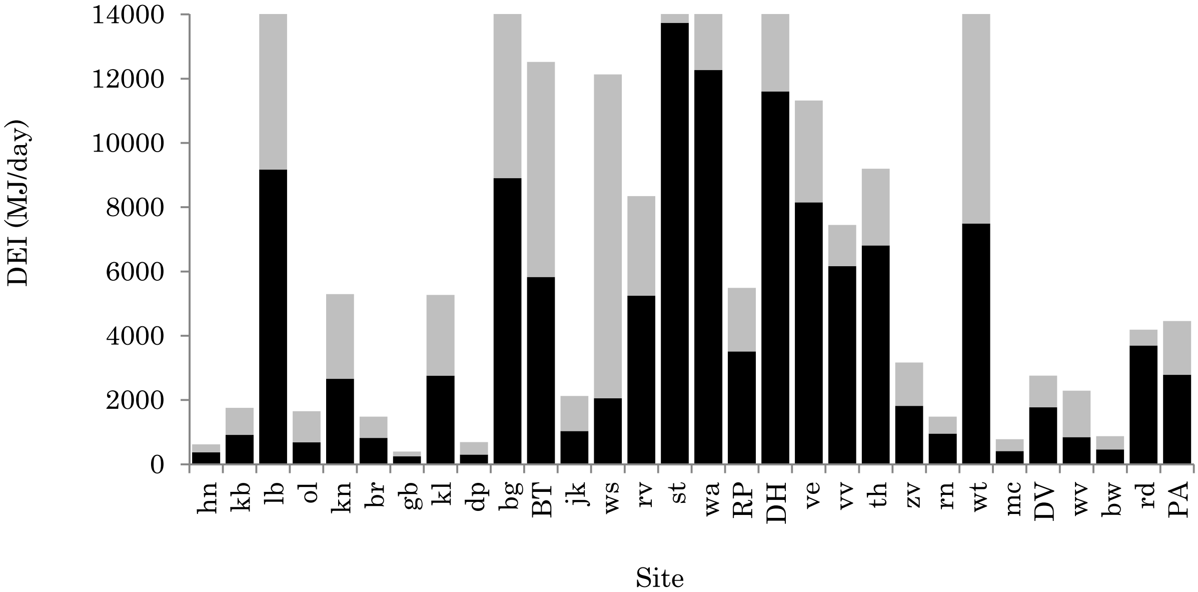


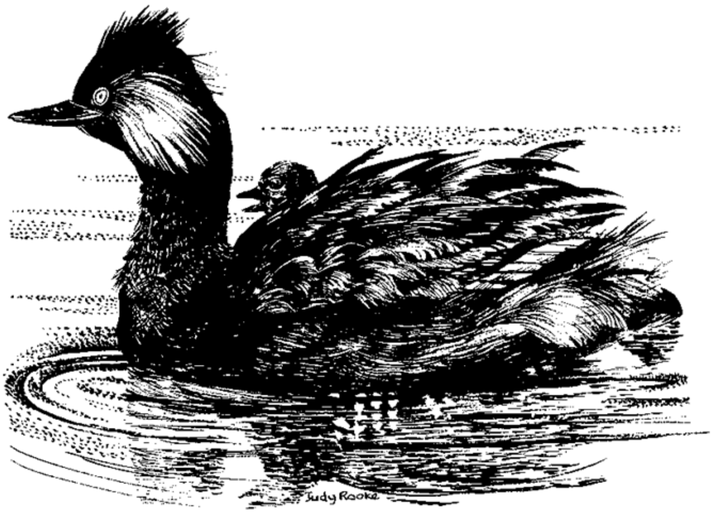
Figure 5.12 DEI values for 30 wetland sites in the Western Cape in summer (dark bars) and winter (grey bars). See text for calculation of DEI values. For site codes refer to Table 5.1.

Appendix 5.1 List of 71 waterbird species used in the correspondence analyses (CA). The Ref. no. corresponds to the number used in the CA plots. Species with abbreviations should be used together with Figures 5.9 and 5.10.

Ref. no.	Species	Abbr.	Ref. no.	Species	Abbr.
1	African Snipe		37	Little Egret	
2	African Black Oystercatcher	ABO	38	Little Grebe	LG
3	African Darter		39	Little Stint	
4	African Marsh-Harrier		40	Maccoa Duck	MD
5	African Sacred Ibis		41	Malachite Kingfisher	
6	African Spoonbill		42	Marsh Sandpiper	
7	Black-crowned Night-Heron		43	Pied Avocet	PA
8	Black-headed Heron		44	Pied Kingfisher	
9	Black-necked Grebe	BNG	45	Purple Heron	
10	Blacksmith Lapwing		46	Red-billed Teal	
11	Black-winged Stilt	BWS	47	Red-knobbed Coot	RC
12	Cape Cormorant	CC	48	Reed Cormorant	
13	Cape Shoveler	CS	49	Ruff	
14	Cape Teal		50	Sanderling	SL
15	Caspian Tern	CT	51	Sandwich Tern	
16	Cattle Egret		52	South African Shelduck	SAS
17	Common Greenshank		53	Southern Pochard	SP
18	Common Moorhen		54	Spur-winged Goose	
19	Common Ringed Plover		55	Swift Tern	ST
20	Common Sandpiper		56	Three-banded Plover	
21	Common Tern		57	Water Thick-knee	
22	Curlew Sandpiper	CSP	58	White-breasted Cormorant	WBC
23	Egyptian Goose	EG	59	White-fronted Plover	WFP
24	Eurasian Curlew		60	White-winged Tern	
25	Grey Plover	GP	61	Wood Sandpiper	
26	Glossy Ibis		62	Yellow-billed Egret	
27	Great Crested Grebe	GCG	63	Yellow-billed Duck	YD
28	Great White Pelican	GWP	64	African Purple Swamphen	
29	Greater Flamingo	GF	65	Bar-tailed Godwit	
30	Grey Heron		66	Common Whimbrel	
31	Grey-headed Gull		67	Giant Kingfisher	
32	Hadeda Ibis		68	Great Egret	
33	Hartlaub's Gull	HG	69	Osprey	
34	Kelp Gull	KG	70	Ruddy Turnstone	RT
35	Kittlitz's Plover		71	Whiskered Tern	
36	Lesser Flamingo	LF			

Chapter 6

Synthesis and recommendations



Conservation importance – the Waterbird Conservation Value score

Nowadays it is becoming increasingly important to develop rapid conservation assessment tools in biodiversity conservation in order to prioritise research and conservation needs. Wetlands are also under increasing threat from development and their ecological importance often goes unnoticed. One example of such a tool is the Alerts System developed in the United Kingdom (Austin et al. 2006). This system, through regular census data, provides a standardised method for identifying the direction and size of changes in waterbird numbers at various spatial and temporal scales.

Kuijken (2006) traced the development of concepts in waterbird conservation; these started to take root from the 1930s, resulting in the initiation of the "International Wildfowl Inquiry" in 1937. Kuijken (2006) described several series of meetings over a period of four decades which culminated in the Ramsar Convention; the final text was agreed upon on 2 February1971, the date now commemorated annually as "World Wetlands Day". The Ramsar Convention (full title: "The Convention on the Conservation of Wetlands of International Importance especially as Waterfowl Habitat") introduced the 1% criterion (see Chapter 2) which allowed wetlands to be designated as internationally important based on a threshold level of 1% of the estimated global or bio-geographical population; waterbird population estimates are now readily available and have been based on census data through the International Waterbird Census programme of Wetlands International (Gillesen et al. 2002) in which South Africa participates through the African Waterbird Census programme (Diagana et al. 2006). This threshold level was deemed to be biologically and ecologically significant. The application of the criterion can be used fairly quickly and has allowed rapid assessments to be made of the global importance of wetlands.

From the waterbird perspective, the 1% threshold has remained the key tool in determining the conservation status of wetlands for four decades. It is therefore with some trepidation that the Waterbird Conservation Value (WCV) score, developed in Chapters 2 and 3 of this thesis, is introduced. This new measure should not be viewed as a competitor to the 1% threshold approach, but should rather be seen as a natural extension of this concept. It makes use of the 1% threshold levels to provide a cumulative score which can be used to rapidly assess the waterbird conservation importance at the site. It considers the contributions of all species to evaluating the importance of a site, not only those that exceed the 1% threshold. I therefore recommend that the WCV scores be adopted in addition to the traditional approach to assist in the ranking of the importance of wetlands, not only in South Africa, but throughout the world. This tool can be used to help prioritise wetlands of international importance in a country, and will aid biodiversity conservation planning at national level. Importantly, changes to the site WCV scores on an annual basis will allow regular assessments to be made on a continuous scale. A substantial decrease in the score could then act as an 'alert' for (a) monitoring changes in certain species populations, notably threatened or endemic species and (b) providing the relevant managing authority at the site to investigate possible causes for such declines. The tool will also be useful in assisting climate change studies for monitoring changes in bird populations (de Villiers 2009). The shortcoming of the traditional approach of simply counting the number of species that reach the 1% threshold at a site is that it is rather insensitive to the changes in abundance of waterbirds, only changing when the abundance of a species either increases above, or decreases below, the threshold.

Waterbird censuses and conservation implications

The counting and monitoring of waterbird populations at wetlands allows researchers and managers to describe the diversity and abundance of waterbirds at site-level. The data can further be used to assess aspects such as seasonality, identification of threatened species, identification of sites supporting significant numbers of birds, energy consumption and, where long-term monitoring, for periods of a decade or longer has occurred, population trends. At larger spatial scales, these data can be used to look at patterns of distribution and abundance and relative importance of wetlands in a regional context and assess conservation priorities for waterbirds.

In this thesis, I included the above aspects to investigate and assess the regional importance of wetlands for waterbirds in the winter rainfall region. From the five site assessments (Chapters 3 and 4 and Appendices A–D) the following aspects emerged:

- The WCV score is a useful tool to assess regional importance of wetlands and allows rapid assessment of priority species within a defined region.
- The uses of visual analytics (colour-coded histograms and radar plots) are a useful and convenient way of displaying the overall conservation importance of sites.
- The WCV score can be used in detailed site studies to assess specific site issues. For example the conservation priorities of the opening and closure of the mouth of the Bot River estuary can be assessed through this method (Chapter 4)
- Conservation value of a site is not necessarily based on large abundance values for species. Using the WCV score, the ratio of abundance (a count) to the 1% threshold level is more significant. Because the denominator (1% level) for certain species is high, ratios will be small even when large numbers of birds are present.

Thus species with large numbers relative to their 1% level will have higher conservation priority and site significance.

- Natural wetlands, Rocher Pan, De Hoop Vlei and Bot River estuary supported more birds and had greater conservation value than man-made wetlands; the mean WCV scores during summer were almost double those of Paarl WWTW and Droëvlei Dam (Table 3.1). This phenomenon is well known and widely accepted (Tourenq et al. 2001, Ma et al. 2004, Paracuellos and Tellería 2004, Raeside et al. 2007) and highlights the importance of natural wetland systems for waterbirds in the WRR.
- Although artificial wetlands (Paarl WWTW and Droëvlei Dam) supported fewer numbers of birds and had less conservation significance (i.e lower WCV scores) than the natural wetlands, they did play a role in offering suitable alternative habitats to waterbirds (Fuller and Glue 1980). Consequently they also contributed to maintaining regional and global (e.g. White-winged Tern) waterbird populations in the WRR (Gibbs 1993).
- Wetland inundation and hydrological changes impact on the way in which waterbirds utilise sites. A seasonal wetland such as Rocher Pan (Appendix C) supports waterbirds for a certain period of time but as the wetland dries up they need to search out more permanent wetlands. Bot River Estuary (Chapter 4) and De Hoop Vlei (Appendix D) can support birds all year round but changes in water-levels and salinities impact on changes to the waterbird communities that use these sites.
- Patterns of mean abundance for most other species were variable and it was difficult to discern movement patterns between sites based on the census data provided. This is largely due to the unpredictable nature of environmental conditions at South African wetlands; this was evident when assessing responses of birds at the Bot River estuary (Chapter 4) and Rocher Pan (Appendix C).
- Red-knobbed Coot showed preference for larger, natural waterbodies. It was the most abundant species at the Bot River Estuary, De Hoop Vlei and Rocher Pan. These birds generally occur in large congregations, particularly when not breeding, and therefore require large waterbodies with sufficient aquatic plant material. Although Red-knobbed Coot is not uncommon or under threat, the fact that it has large populations in the Western Cape does infer that safeguarding these sites is important for this species.

Chapter 5 elucidated further on the results of the five site analyses and considered associations between 30 wetlands in the Western Cape. In summary, this chapter concluded that:

- There were strong associations between wetlands of the same type. Estuaries or estuarine bays that were permanently open to the sea (e.g. De Mond, Langebaan Lagoon, Berg River estuary, Knysna Lagoon), supported increased shorebird populations particularly Palearctic migrants during summer. Freshwater wetlands (e.g. Paarl Waste Water Treatment Works, Droëvlei Dam, Radyn Dam, Wildevoëlvlei) were dominated by waterfowl-wader communities.
- Wetland conservation status did not seem to play an important role in determining waterbird conservation importance. This infers that waterbirds selected sites based on the physical characteristics of the wetland.
- Waterbird Conservation Value (WCV) scores were generally higher at larger wetlands than smaller sites; large sites were able to support larger species populations and therefore had greater conservation value.
- Daily Energy Intake was greatest at large sites which support larger populations of waterbirds than smaller sites; however this can vary seasonally and for wetland type. For example, at Langebaan Lagoon large numbers of migrant shorebirds remove most of the energy from the wetland during summer a time of high productivity; in winter when the majority of the migrants were absent, flamingo populations increased; with higher biomass values higher DEI values were recorded during winter than summer; the same applied to the Berg River estuary which had higher DEI values in winter compared with summer.
- Strandfontein WWTW, Langebaan Lagoon and Berg River Estuary emerged as the top three sites in the Western Cape for waterbird conservation (Table 6.1); this was in terms of making significant contributions to global and regional waterbird populations. These sites should be conserved at all costs.

Further research and recommendations

What will shape the monitoring and conservation of waterbirds in South Africa, and in particular the winter rainfall region of the Western Cape, into the future? It is clear from this thesis how different sites were surveyed under different counting protocols and how the data were assessed based on these protocols. It was also evident that changes in the occurrence and seasonal abundance vary spatially and temporally and that certain sites do support more conservation worthy species than others.

However, how do we incorporate these and other variables to ensure waterbird monitoring delivers the right kind of information and that the right kind of analyses are undertaken? There are four main issues that scientists, researches and managers need to consider when considering managing future waterbird populations in the winter rainfall region of South Africa:

(a) Improved census data for population estimates
(b) Impacts of climate and environmental change
(c) Site characteristics and management
(d) Landscape conservation and management

These issues are explored further in the following sections.

(a) Improved census data for population estimates

One thread running through this thesis has been the concept of deriving a Waterbird Conservation Value score as an additional method to assess wetland importance (Chapters 2 and 3). Because the calculation of the score is based on the 1% threshold, which are derived from population estimates, the resultant scores are dependent on the population estimates (Chapter 2). These estimates and 1% thresholds are provided in 'Waterbird Population Estimates' (Wetlands International 2006) using data sourced from the International Waterbird Census (IWC) programme. CWAC supplies South African waterbird census data to the IWC and 1% thresholds are sourced for South African waterbirds.

The 1% thresholds cannot be applied consistently across all waterbird groups (Wetlands International 2006). This is because population data are often not available or are unreliable. For certain species groups (e.g Anatidae, Rallidae, some Scolopacidae) Wetlands International maintains that population estimates are unknown or are based on best-guess estimates because species are difficult to survey or occur in small numbers. In these cases 1% threshold levels are not assigned due to the lack of or poor quality of census data.

Often population estimates for species are based on a single population within a large geographic region. Within Africa, for example the 1% threshold for Goliath Heron is 3000 given for a single sub-Saharan population (Wetlands International 2006). In South Africa this threshold would never be reached for this species – the highest count for Goliath Heron at a single wetland in South Africa is 161 (CWAC, unpublished data, Animal Demography Unit). Such a count would generally reflect a large proportion of the 'national population' but loses its significance in the African context. As such, this site is not recognised as being important for this species. This begs the question of whether some population estimates are reliable or even bias to certain regions within a species range where densities are higher. Similar scenarios exist for other South African species which have sub-Saharan populations: Hamerkop, 1% threshold is 10 000, Black Heron, 1 000 and Blacksmith Lapwing, 10 000. Where subspecies have been described for a species, population estimates for these subspecies (or sub-populations) tend to be more reliable and 1% thresholds more realistic. At these sub-species scales WCV scores will then have more meaningful conservation outcomes. Globally there are 546 waterbird populations (either species or sub-species) whose population sizes are unknown or uncertain; 52 of these populations occur in Africa (Wetlands International 2006).

Based on the above, there is a need to develop strategies to improve census techniques and monitoring of waterbird populations in Africa, and South Africa, to provide improved population estimates. In turn this would enable a more robust application of the 1% threshold and WCV score and better conservation planning. In addition, there is an urgent need to develop and formalise national and provincial waterbird thresholds in South Africa. The CWAC data currently has a 20-year dataset from which initial population estimates could be derived. Setting national and provincial thresholds would allow for a more focussed approach and have greater relevance to national and local waterbird conservation initiatives in the region and within the Western Cape. Consequently, increased responsibility would then be placed on regional or national conservation bodies to ensure adequate protection of sites for species.

(b) Impacts of climate and environmental change

With large parts of the Western Cape, and winter rainfall region, predicted to become hotter and drier with more erratic rainfall particularly along the West Coast (Simmons et al. 2004, Midgley et al. 2005), changes to seasonal rainfall and therefore landscape elements are likely to occur. Ephemeral wetlands or at least those which show substantial drying during the dry season, are likely to stay drier for longer, and therefore have direct impacts on waterbird abundance at particular sites. From this thesis Rocher Pan and Droëvlei Dam are strong candidates in this category. De Hoop Vlei and Bot River Estuary may receive less inflow and increased water-level fluctuations may occur along with increased evaporation associated with slighter higher summer temperatures and strong prevailing winds. Paarl WWTW may be the least impacted site mainly due to the nature of the treatment works where there is a constant supply of water to the maturation dams.

Since rainfall is considered to be a primary proximal factor to which waterbirds respond (Winterbottom and Rowan 1962, Immelman 1970, Burbridge and Fuller 1982, Whitehead and Saalfeld 2000 and Roshier et al. 2002) and that reflect varying patterns of waterbird abundance, distribution and timing of breeding, it is important to consider it here in more detail. Tyson (1986) states that in the southern hemisphere, El Niño Southern Oscillations (ENSO) cause increased rainfall variability and prolonged droughts in arid and semi-arid environments; similarly La Niña events result in prolonged wet periods. El Niño events have become more frequent in the last 20–30 years in Africa and Asia that have resulted in more frequent and prolonged droughts occurring (Finlayson et al. 2006). These events are also experienced in South America and have impacted bird populations (e.g. Schlatter et al. 2002). Animal and plant communities in these areas need to respond and/or adapt to these changing wet–dry cycles, particularly during long drought periods (Dean et al. 2009). As most of the winter-rainfall region is considered a dry, semi-arid environment (Tyson 1986, Schulze 1997), and with the rainfall and temperature changes forecast for the region, longer dry spells with less prolonged rain is bound to impact on waterbirds, and other biotic communities. For waterbirds, the changes are likely to impact generally on all aspects of their ecology although changes to populations, foraging areas (especially at coastal wetlands), timing of breeding and migratory/movement patterns may be worse affected (Schlatter et al. 2002, Finlayson et al. 2006); for the latter favoured roosting, feeding or moulting sites may no longer hold water for any length of time which could alter selection of sites for these activities. It is unsure exactly how these changes will take place, especially within African and South African ecosystems (de Villiers 2009), and why there is a need to conduct appropriate scientific studies and research to monitor responses to this change. Trends in bird distribution and populations may well be driven by climate change, but these do not operate independently; aspects such as land-use and landscape changes need to be considered as complimentary causative factors. de Villiers (2009) and Finlayson et al. (2006) concur that ongoing monitoring and compilation of long-term bird datasets and bird inventories provide immensely valuable data to begin to look at detecting changes, which may vary from species to species.

For waterbirds in South Africa, CWAC is providing this kind of data and showed that Curlew Sandpiper numbers have declined by as much as 40% at Langebaan Lagoon over three decades (Harebottle and Underhill 2006). Through counts of first-year birds at non-breeding sites in South Africa during the peak austral winter (June–July), breeding success can be monitored and overall population changes measured for this species; long-distance migrant shorebirds are likely to be the first casualties of climate change in the

Siberian tundra (Zöckler 2002, de Villiers 2009). This provides evidence of the success and importance of programmes like CWAC and a call for it to continue on an on-going basis into the future.

Environmental modelling to aid data interpretation

Where rainfall was considered in the site analyses, there were indications that wetness (cumulative rainfall over time) may be an important factor influencing occurrence of species at some sites. Modelling the response of species to regional wetness would be a useful future research output and would complement similar studies carried out in Australia by Chambers et al. (2005) and Chambers and Lyon (2006). This modelling becomes particularly relevant when considering the impacts of future climate change shifts in the region (see above). Consequently, I strongly recommend that existing and adaptive modelling techniques be considered and applied for future analyses, and perhaps using longer time-series data. Aspects of the models, such as improving the quality of the rainfall and salinity data, and including other climatic variables (e.g. temperature) and site variables (e.g. water-level, volume of water), needs to be considered to improve the power of the models, as these factors may have impacted on the outcome of the initial results. This modelling may have the desired impact of predicting which wetlands may be most impacted and which species most affected by shifts in rainfall patterns. In the same winter rainfall region in which I worked, Oschadleus (2005) found that the initiation of moult in weavers was correlated to the end of the wet season, while other studies (Gentilli and Bekle 1983, Woodall 1985) have found strong links between rainfall and inundation and other climatic variables.

(c) Site characteristics and management

Changes at landscape or global levels and their impacts are difficult to assess in the medium-short term. However, the physical characteristics of the wetland site and any changes are likely to be assessed more rapidly in the short-term, and often it is these short-term impacts which have immediate consequences for waterbirds. Although some site information is collected for CWAC, it is often done on a casual or *ad hoc* basis. For interpretation of waterbird surveys to be done properly more systematic collection of site data is required, particularly of water-quality and food abundance. Some of the results in this thesis have used such data (e.g. salinity and water-level data, Chapter 4) and it has aided in drawing better conclusions than if this data was not available.

There is a need for holistic wetland management particularly for critical and important sites where waterbirds occur. For sites that fall within protected areas management plans should include regular surveys of aquatic plants at the wetland, both of submerged macrophytes (e.g. *Potamogeton* spp. and *Ruppia* spp.) and emergent vegetation (reeds and sedges). These are important site attributes for waterbirds, particularly waterfowl, which make use of the plants as a food source and nesting material (e.g. Red-knobbed Coot which is an important wetland species in the winter rainfall region).

(d) Landscape conservation and management

An increasing number of waterbird and wetland researchers and managers are becoming aware of the landscape approach to conserve these habitats (Flather and Sauer 1996, Haig et al. 1998, Erwin 2002, Tori et al. 2002, Chambers and Loyn 2006, Dodman and Diagana 2006). They cannot be looked at in isolation, especially for waterbirds which are highly mobile. Large-scale and long-distance movements occur between sites (Oatley and Prŷs-Jones 1986, Underhill et al. 1999) and as such conservation of species and populations needs to take place at levels that cross biomes and often political boundaries. Wetlands serve different purposes – where one site provides a safe place to breed another site provides good foraging opportunities; when one site dries up another site provides permanent water as a safe refuge. Niemuth and Solberg (2003) found that water availability determined shifts in waterbird distributions rather than responses at local level, again emphasising a broader landscape approach to wetland and waterbird conservation ecology.

The regional analyses undertaken in this thesis has provided insights into how different wetlands in different parts of a climatic region often support varying waterbird populations; conservation value assessments were also carried out to determine important sites and priority species. Annual survival of waterbirds invariably depends on the availability of different wetland types, different hydrological processes, varying wetland productivity and connectivity between wetlands at landscape level (Haig et al. 1998, Paracuellos and Telleria 2004, Traut and Hostetler 2004, Taft and Haig 2006, Paracuellos 2006, Lank and Nebel 2006). This concept and approach to waterbird conservation has long been recognised in South Africa (Siegfried 1970, Zaloumis and Milstein 1975) but no formal policies or co-operative agreements exists between provinces or even neighbouring countries in order to ensure commitment to this. This is something that needs to be considered in the near future.

Taking this further to the global level, where the landscape approach becomes important in terms of long-distance migrants, agreements such as the African-Eurasian Waterbird Agreement (AEWA), a multi-national agreement under the Convention on Migratory Species (CMS) (Boere and Lenten 1997) help provide measures and access to resources to conserve migratory waterbirds and their habitats at an international level. South Africa is a signatory to the CMS and AEWA and therefore has committed itself to implement activities in this regard. These agreements could aid in setting up national policies and action plans (Zaloumis 1993, Arinaitwe 1995) and possibly a waterbirds alert system as has been devised in the United Kingdom (Austin et al. 2006).

As part of the landscape approach, monitoring of movements of waterbirds within the landscape or further afield is crucial; this helps researchers, managers and policy makers better understand how waterbirds use the landscape and which sites are more important than others (e.g. Stroud et al. 2006). In addition, it complements CWAC data, providing a more holistic, integrated approach to monitoring and managing waterbird populations in South Africa.

There is a lack of information on waterbird movements in South Africa at every scale except those of long-distance inter-continental migrants, whose annual movements, in at least broad terms, are relatively well understood (Underhill et al. 1999). However, the movements of waterbirds within Africa, southern Africa, South Africa and within the winter rainfall region of the Western Cape are poorly understood (Underhill et al. 1999). It seems to me that the poorest understanding is on the smallest scale. One of the original goals at the outset of this thesis was to test the idea that waterbird counts would help us understand regular seasonal movements of waterbirds between wetlands of the Western Cape. I had hoped that increases at wetlands in one region would be compensated for annually by increases at wetlands in another region. In analyses not presented within the body of this thesis, but implicit in the results, I failed to find any patterns. At a regional scale of the Western Cape, it seems difficult for census information to discern regular movements of waterbirds and linkages between wetlands. Within this region, site-level information is probably best treated as providing information within the scale of the site.

A long established method of discerning patterns of waterbird movements is by ringing (e.g. Siegfried 1967, Oatley and Prŷs-Jones 1986, Little et al. 1995, Petrie and Rogers 1997). Underhill et al. (1999) provided a summary of waterbird ringing recoveries in southern Africa. They concluded that many resident waterbirds displayed dispersal or movements but generally no movement or migratory patterns were discernible. One of their recommendations to solve this problem was to establish colour ringing schemes, with individually marked engraved rings, to supplement the traditional recovery data. In response to this, Harebottle and Gibbs (2006) established such a long-term waterbird ringing programme in the Western Cape. The programme aimed to study dispersal and movements of colonial waterbirds, in particular African Sacred Ibis. Although the database generated by this programme has not yet been analysed, it is abundantly clear that this project is not going to solve the problem of uncovering patterns of waterbird movement in the Western Cape (unpubl. data). It will however provide the data resources for estimates of survival rates using capture-mark-recapture modelling.

A country-wide, long-term coordinated waterbird ringing programme would certainly meet the need to monitor movements and survival of waterbird species in the Western Cape and elsewhere in South Africa. These activities, which could be coordinated through the African Waterbird Ringing Scheme (AFRING, see Harebottle et al. 2005) could focus on waterfowl and waders, two groups which already have been subjects of previous or ongoing ringing programmes in the Western Cape (Harebottle 2005, Harebottle and Gibbs 2006).

During the analyses period of this thesis, new technologies have emerged and the problem of understanding waterbird movements and linkages between sites is now tractable, though expensive. The development of GPS data loggers small enough to be attached to a waterbird has the potential to revolutionize our knowledge of the details of waterbird movements within the Western Cape. In the ocean adjacent to my study area, these data loggers have been attached to seabirds of similar sizes to the waterbirds; the information retrieved from the GPS loggers applied to Bank Cormorants *Phalacrocorax neglectus* (Ludynia 2010a), African Penguins *Spheniscus demersus* (Petersen 2006, Ludynia 2010b) and Cape Gannets *Morus capensis* (Mullers et al. 2009) has not only provided critical information about the biology of these species, it has also generated recommendations essential for their conservation.

Concluding remarks

The mosaic of wetlands described in this thesis and the intra- and inter-abundance, seasonality and conservation value of species all highlight the collective role that these wetland sites play in supporting waterbird populations in the winter rainfall region. Waterbirds are habitat-dependent organisms; their occurrence and abundance rely on the quantity and quality of habitat that is available. Consequently, they are highly adaptive and mobile and respond to changing site, landscape or environmental conditions, often rapidly (Simmons et al. 1999, Hermann et al. 2004, Robledano and Pagán 2006, Celdrán and Aymerich 2010). Some species are nomadic (e.g. Pied Avocet and Black-winged Stilt) wandering around the landscape in short bursts in search of favourable sites. Ultimately, they are a complex and diverse group of birds with varying life histories and survival strategies which makes monitoring their populations often challenging, particularly at landscape and global levels.

Physical changes at site level or within the landscape, changes waterbird communities at various spatial scales, and coupled with regular phenological factors (annual moult migrations) alter the dynamics of populations at local, regional and even global scales. As such, the inter-connectivity and management of key wetland sites is critical to the long-term conservation of waterbirds and their habitats (Haig et al. 1998, Roshier et al. 2001), and why ongoing, long-term monitoring and regular conservation value assessments are crucial in further understanding how and why waterbirds use wetlands, not only in the winter rainfall region but at wider spatial and tighter temporal scales.

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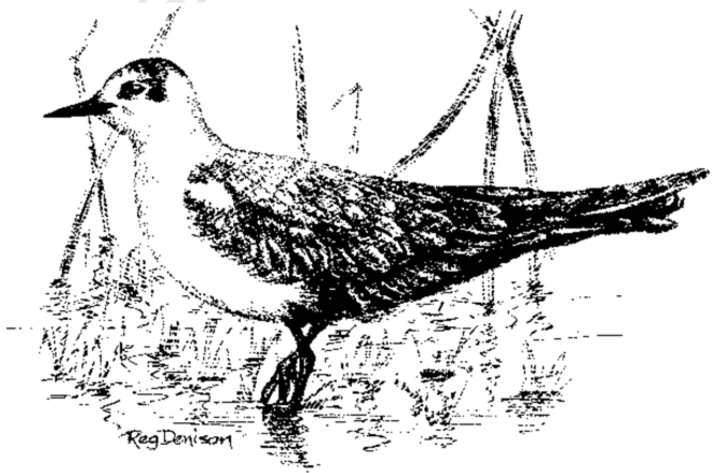
APPENDICES

Appendix A

Waterbirds at Paarl Waste Water Treatment Works, South Africa, 1994–2004: seasonality, trends and conservation importance



Abstract

The numbers of waterbirds at Paarl Waste Water Treatment Works, South Africa were counted monthly from May 1994 to April 2004. Seventy-two waterbird species were recorded, of which 33 species (46%) were recorded breeding. Mean summer and winter counts were 2 822 ± 504 and 1 651 ± 251 birds, respectively. Summer peaks were driven primarily by large numbers of White-winged Terns (mean summer count = 858 or 34% of total count). Resident species dominated from December to April, whereas Palearctic migrants peaked from December to March. Ducks and geese had greatest numbers from December to April and resident waders and grebes peaked from April to July. Flamingos peaked in October and November with another small peak in June. Gulls and terns had two peaks, one in November–March, driven by migrant White-winged Terns, the other in July and August, driven by abundance of resident Hartlaub's Gulls. White-winged Terns showed the greatest decline (82%) of all species. Influx of Little Grebe and Red-billed Teal during winter showed a positive correlation with rainfall, while Egyptian Goose, Yellow-billed Duck and Cape Shoveler numbers declined as winter and spring rainfall increased. Paarl Waste Water Treatment Works ranked as the second-most important wastewater treatment works for waterbirds in the Cape Town metropole. It supported globally and regionally important numbers of nine species and qualifies as a global and/or subregional Important Bird Area and Ramsar Site.

Plate A.1 View looking northwards from the bird hide overlooking pond B (see Figure A.1)

Introduction

Globally, and particularly in urbanised areas, human activity has caused the loss of substantial areas of natural wetlands. The establishment of artificial wetlands provides partial compensation for such losses (Masero 2003, Ma et al. 2004). The largest artificial wetlands in many metropolitan areas are 'wastewater treatment works' (WWTW), initially created as sewage works with adjacent settling ponds but now often retained for flood attenuation. WWTW are shallow (mean depths usually less than 3 m), nutrient enriched, and are sustained as permanent wetlands with water levels that are more stable than those of natural wetlands. These features make WWTW attractive to waterbirds (e.g. Fuller and Glue 1980, Hamilton et al. 2005), many species of which occur in numbers that are of conservation importance (e.g. Kalejta-Summers et al. 2001b, Hamilton et al. 2004).

The Paarl Waste Water Treatment Works (hereafter termed Paarl WWTW) is located in the interior regions of the winter rainfall region (WRR) in South Africa; the latter is described in detail in Chapter 1. Within the WRR many small, shallow wetlands become inundated following winter rains. These dry out during the summer and waterbirds that exploit them are forced to move to larger, permanent wetlands (cf. Winterbottom 1960, Kingsford and Norman 2002, Williams et al. 2002). However, most of the region's large natural wetlands are also ephemeral and either dry out annually (e.g. Rocher Pan (Appendix C) or, for various reasons, undergo hydrological and/or vegetational changes on an irregular, interannual basis (e.g. Jakkalsvlei, Bot River Estuary (Chapter 4) and De Hoop Vlei (Appendix D)).

There have been substantial changes to wetlands within the WRR during the past 200 years. Marshy areas have been drained for agriculture, reservoirs have been built in mountainous areas to service towns and to supply water for irrigation, human-related changes in water flow have altered the dynamics of estuary/lake wetlands (e.g. Bot River Estuary; van Niekerk et al. 2005; Chapter 4) and, increasingly, groundwater extraction is threatening shallow ephemeral wetlands (e.g. Wadrif Saltpan; Williams et al. 2002). In the light of the continued degradation of the region's natural wetland habitats, artificial wetlands, especially the larger WWTW, have become increasingly important in sustaining regional populations of waterbirds (e.g. Cape Flats WWTW; Ashkenazi 2001, Kalejta-Summers et al. 2001b).

The number of waterbirds at the Paarl WWTW has been counted monthly since May 1994 and here I analyse the results for the 10-year period 1994–2004. No previous analyses of waterbirds have been undertaken at this locality. The aims of the study were (1) to highlight the importance of Paarl WWTW for particular waterbird species relative to their numbers on global (Ramsar threshold), subregional (IBA threshold), provincial (Western Cape Province, South Africa) and local (Greater Cape Town Metropolitan Area, hereafter termed Cape Town metropole) levels; (2) to emphasise the importance of an artificial wetland for biodiversity conservation and as partial compensation for the earlier regional losses of natural wetlands and floodplains, especially so in metropolitan areas; and (3) to provide insights into the needs and movements of waterbirds at regional, annually ephemeral or irregularly ephemeral wetlands by assessing the seasonal pattern of use of species at this stable water-level wetland.

Study area

Paarl WWTW (33°40′ S, 18°58′ E) is situated between the towns of Paarl and Wellington, c. 50 km east of Cape Town. It is bordered to the west by the Berg River and to the east by the Cape Town–Johannesburg railway line, and lies within the WRR of the Western Cape (Figure A.1). The works are located on the eastern boundary of the Cape Town metropole, defined here as the area within a 50 km radius of Cape Town (Figure A.1). The treatment works is located next to an industrial area and the Mbekweni informal settlement; the latter was established during 1996. Paarl WWTW was constructed in the 1930s and has subsequently expanded intermittently in size and thus sewage-handling capacity. Settling and maturation ponds were added in the 1960s and were modified in 1979 when islets were constructed on three of the maturation ponds. After 1992, when a sludge treatment plant was opened, the maturation ponds were decommissioned and treated effluent was discharged directly into the Berg River, bypassing the maturation ponds. However, if the river rises above the effluent outlets and prevents discharge, effluent is diverted to the maturation ponds. These occurrences are irregular and of short duration, but can result in nutrient renewal.

Aquatic habitats at Paarl WWTW consist of an aeration pond (2.2 ha), final effluent pond (3.8 ha), waste sludge pond (4.2 ha), five maturation ponds (58.1 ha) and a network of furrows (Figure Ab). The aeration, effluent and sludge ponds are all steep sided and are c. 3.5 m deep. The maturation ponds (A1, A, B, C and D) range in size from 3.0 ha (Pond A1) to 28 ha (Pond C), are up to 2 m deep and comprise mainly open water with fringing emergent vegetation (mainly Bullrush *Typha capensis*); these ponds have been officially designated as the Paarl WWTW Bird Sanctuary (see Figure A.1b, Plate A.1) and received about 5 000 visitors in 2004 (C Morkel pers. comm.). Small trees (Port Jacskon *Acacia saligna*, *Eucalyptus* spp. and *Olea* spp.) grow on the islets and some are used for breeding by ardeids, cormorants and African Darter. The maturation ponds support two freshwater fish species: Carp *Cyprinus* spp. and Tilapia *Oreochromis mossambicus*, the latter introduced in the late 1980s.

Methods

Counts of waterbirds were carried out monthly between May 1994 and April 2004. Between May 1994 and October 2000 counting was done in the afternoon (1500–1730). From November 2000 to April 2004 surveys were done in the morning (0900–1130). For most species of waterbirds this change would have had minimal effect because, although birds move between different areas within the site, few birds move into or away from Paarl WWTW during the day (AJ Williams and Y Weiss pers. obs.). Counts were recorded for individual ponds and furrows but for the purpose of this analysis counts have been pooled.

Waterbirds and waterbird groups are defined in Chapter 1 and species are drawn from the list provided in Appendix 1.3 of Chapter 1 and based on Hockey et al.(2005). Data analyses were restricted to those species which were recorded on more than 25% of counts and in numbers that exceeded 10 individuals. These species described most of the variability at the wetland and revealed discernable patterns and trends. In some cases species have been included that do not meet these criteria as they show interesting patterns. For the analyses I focused on the resident species since little is known about their patterns of occurrence and movements.

Overall abundance, seasonality, and inter-annual variation analyses were undertaken. Overall abundance was assessed using basic statistics (mean, standard deviation, minimum, maximum). Seasonal analyses were based on the occurrence status of species (resident or migrant), and carried out for individual species, species groups and feeding guilds (where applicable) (Appendix 1.3). Linear regression models were used to test for statistically significant trends and only species showing significant positive or negative trends are displayed graphically.

The conservation importance of Paarl WWTW was assessed based on the Waterbird Conservation Value (WCV) score described in Chapter 2. Scores were computed and interpretations made based on methods outlined in Chapter 2; values of 10 or more were interpreted as being of conservation significance for the site but this was carefully interpreted on the basis of the number of species that reached or surpassed the 1% threshold level. In addition, an overall site score was calculated which was based on the computation of the minimum, lower quartile, median, upper quartile and minimum. Both monthly and site WCV scores were calculated from surveys during the study period. Where a 1% level was not available this value was omitted from the calculation.

In addition to the WCV scores, I assessed sub-regional importance and used the 0.5% index based on the sub-regional IBA thresholds in Barnes (1998) (Appendix 1.4, Chapter 1). To gauge the site's significance at a provincial and local level I computed the percentage that the maximum count of each species contributed to the Western Cape and Cape Town metropole population estimates; only species comprising 5% or more for either or both population thresholds were deemed important. These population estimates were generated from the CWAC dataset (Animal Demography Unit, unpubl. data) for the period 1992–2006 and based on the sum of the maxima of each species across all wetlands in the Western Cape that were surveyed for CWAC (Appendix 1.4, Chapter 1). A subset of these sites were then selected to calculate the populations estimates for species in the Cape Town metropole.

The relationship between seasonal rainfall and waterbird abundance for species and for groups of months was also examined. I correlated the sums of monthly rainfall totals with the sums of the count for the selected waterbird species over the same period; all linear regressions were based on a sample size of 10, unless otherwise indicated. Rainfall data were obtained from the South African Weather Service's recording station located 4 km south of Paarl WWTW.

Breeding records obtained incidentally during the counts were used to describe the seasonality of species breeding at the works, and included the species breeding on the islets. A species was confirmed breeding if eggs or young were seen in a nest, an adult bird was observed incubating, or, in the case of species using hidden nests, precocial young (e.g. ducklings) were seen with adults. Results are expressed as the number of breeding pairs per month.

Results and species-level discussion

Species richness and overall abundance

During the 10-year study period, 80 summer and 40 winter surveys were conducted. Seventy-five species of waterbirds were recorded, of which 20 (27%) were recorded in 25% or less of all the surveys (Table A.1). The mean number of species recorded was similar in summer (38) and winter (36). The mean number of waterbirds was 74% greater during summer (2 967.6 ± 504.4) than during winter (1 700.9 ± 250.5) (Table A.2). This difference was due primarily to three species — the Egyptian Goose, White-winged Tern and Hartlaub's Gull — which together formed 56% of the number of waterbirds in summer. In winter, five species formed, on average, 58% of the total population. These species were Hartlaub's Gull, Egyptian Goose, Black-winged Stilt and Little Grebe. The mean number of waterbirds counted per month ranged between 1380 in September and 3532 in January. The highest single count was of 5364 birds in January 1995.

Resident waterbirds

Generally, numbers of resident species increased from September–December, peaked from January to April and decreased between May and August (Figure A.2). In summer, Egyptian Goose, Hartlaub's Gull and African Sacred Ibis were numerically dominant accounting for 24%, 13% and 7%, respectively, of the resident waterbird population (Table A.2). Hartlaub's Gull, Egyptian Goose, Black-winged Stilt and Little Grebe were the most abundant resident species during winter comprising 18%, 13%, 12% and 10%, respectively, of all waterbirds (Table A.2).

Waterfowl

The Egyptian Goose was numerically the dominant waterbird species at Paarl WWTW. Within the WRR this species breeds mainly in August–September (Hockey et al. 1989) when spring grass is available for their goslings. Numbers of geese at Paarl WWTW increased in December/ January and remained high (maximum 1341 in January 2001) until the onset of winter rains when there was a rapid dispersal away from the site (Figure A.3), presumably to recently filled ephemeral wetlands and farmlands (Maclean 1997a). The maximum number of breeding records was five broods seen in September (Table A.3). The number of geese using Paarl WWTW increased significantly through the 10-year period in both summer and winter (summer $r = 0.75$, $p < 0.05$; winter $r = 0.86$, $p < 0.01$; Figure A.4), and the numbers during the summer counts doubled over the decade. Spur-winged Goose, far less numerous ($\bar{x} = 7$, maximum 118; Table A.2), also showed a statistically significant increase ($r = 0.79$, $p < 0.01$) in numbers during the summer months at Paarl WWTW (Figure A.4); numbers increased from an average of four birds from 1994–1998 to 16 from 1999–2003.

Cape Shoveler ($\bar{x} = 50$, maximum 235) was the most abundant duck at Paarl WWTW (Table A.2). It showed a strong seasonal pattern; numbers peaked from October–December and declined from February–June (Figure A.3). This species showed a significant downward trend ($r = -0.63$, $p < 0.05$) during summer (Figure A.4). Yellow-billed Duck ($\bar{x} = 33$, maximum 121) numbers peaked during late summer (March–April) and remained relatively constant throughout the rest of the year (Figure A.3). Winter populations increased from a mean of ten birds during 1994–1996 to 35 birds between

1997–2003. Red-billed Teal ($\bar{x} = 29$, maximum 151) numbers peaked during winter (June–July). Summer populations showed a significant decline ($r = -0.65$, $p < 0.05$) with large fluctuations displayed during winter. The number of Cape Teal ($\bar{x} = 22$, maximum 85) tended to peak in late summer (February–April), although the maximum count for this species was recorded in June. Population levels remained relatively constant during summer and winter ($\bar{x} = 21$ birds), except from winter 1997 to summer 1999 when averages of 35 birds were recorded. Maccoa Duck usually occurred in small numbers (<15 birds; Table A.2) but did exhibit sporadic peaks in January 1995 (71 birds), February 1995 (56 birds) and June 2003 (215 birds). Significant downward trends ($r = -0.83$, $p < 0.01$) during summer were evident for this species (Figure A.4). Southern Pochard occurred mainly from mid-winter (July) to early summer (November) (Figure A.3); a peak of 148 was recorded in October (Table A.2). A single pair bred at Paarl WWTW during September (Table A.3). Numbers in the summer-rainfall region increase in November and breeding occurs there between November and February (Maclean and Harrison 1997). Between December and June less than 10 birds, on average, occurred at Paarl WWTW (Figure A.3) suggesting that at least some pochards are migratory. The number of pochards at Paarl WWTW dropped markedly from peak counts of 148 and 80 in 1994 and 1995, respectively, to peaks of less than 50 birds thereafter.

Numbers of Red-knobbed Coot peaked in October– November (Figure A.3; maximum 260) and Common Moorhen from February to April (maximum 163). Significant downward trends during summer were evident for both Common Moorhen ($r < -0.81$, $p < 0.01$) and Red-knobbed Coot ($r < -0.63$, $p < 0.05$); declining winter trends were evident only for Common Moorhen ($r = -0.89$, $p < 0.01$) (Figure A.4).

Little Grebe (maximum 433) was more abundant at Paarl WWTW during winter ($\bar{x} = 170$) than summer ($\bar{x} = 109$; Figure A.3). Peak breeding occurs in mid-summer (November– January) in the WRR (Hockey et al. 1989) and their winter influx could be related to pre-breeding flocking in which pair formation begins prior to the start of spring breeding (del Hoyo et al. 1992). Since numbers generally declined from November to January (Figure 3) it suggests that Little Grebes disperse from Paarl WWTW and possibly move to summer-rainfall areas when flooding of ephemeral pans occurs during this time (Dean 1997). In the absence of ringing recoveries in southern Africa (D Oschadleus *in litt.*), the pattern of occurrence of the Little Grebe at Paarl WWTW seems to suggest that it undertakes regular movements within southern Africa.

Numbers of Black-necked Grebe, maximum 131 in June 1995, peaked from June to September, and generally fewer than 10 birds were present in other months (Figure A.3). A winter influx of Black-necked Grebes to the winter-rainfall wetlands is well established (Boshoff et al. 1991, Dean and Underhill 1997). Prior to and during the first two years of the surveys, Black-necked Grebes bred at the Vlakkeland ponds, 3 km to the north-east of Paarl WWTW (GB Tong pers. comm.) and in 1994 eggs were noted at this wetland during August, September and November. These Vlakkeland ponds were constructed in 1964 and used as final maturation ponds for effluent water from Paarl WWTW. After the construction of the activated sludge pond (E1) they were drained in 1995. Black-necked Grebes breed from October to November in the WRR (Dean and Underhill 1997), a time when numbers at Paarl WWTW are usually low (less than10 birds on average). In light of the absence of breeding records from the works, Black-necked Grebes most likely found other breeding localities during this time; the closest known breeding locality to Paarl WWTW is Strandfontein Waste Water Treatment Works (Ashkenazi 2001), 60 km south west of Paarl.

Seasonal variation of waterfowl at Paarl Waste Water Treatment Works

The influx and peak abundance of Egyptian Goose, Spur-winged Goose, Yellow-billed Duck and Cape Shoveler during spring and summer indicates their need for a post-breeding, dry-season refuge. Although some birds used the works for breeding (Table A.3), the general decrease in their numbers during winter and spring indicated that most birds bred elsewhere, utilising temporary wetlands that filled during the winter. Following breeding, as temporary water bodies dried out, the permanent water provided by Paarl WWTW acted as a refuge for these species (Maclean 1997a, b, c). For Egyptian and Spur-winged Goose, the works was also used as a moulting site (DMH pers. obs), the deep water ponds providing the safe habitat required for them to moult. Cape Teal, Maccoa Duck, Red-knobbed Coot and Common Moorhen showed no clear seasonal patterns but exhibited periods during which numbers peaked (usually during summer) suggesting they were mostly sedentary species with only sporadic movements.

Little Grebe and Red-billed Teal were the only waterfowl species that showed strong winter peaks. Breeding peaks for Red-billed Teal in the WRR occurs from August to October (Maclean 1997d) and winter influxes probably reflected prenuptial flocking associated with peak rainfall in the WRR. In contrast, winter peaks for Little Grebe confirmed large-scale immigration into Paarl WWTW after breeding. The decline in numbers of most waterfowl in early winter coincided with the onset of winter rain, particularly for Yellow-billed Duck and Cape Shoveler (see below).

Relationship with rainfall

In southern Africa, waterfowl occurrence patterns are usually related to the species' annual cycle and rainfall (Rowan 1963, Siegfried 1965a, b, Heÿl 1993, Little et al. 1995).

At Paarl WWTW, the occurrence of several waterfowl species varied according to rainfall patterns. For Egyptian Goose, patterns varied between years; when the total rainfall between May and July was high (i.e. early onset of winter rain) the dispersal from Paarl WWTW was earlier than in years when the onset of winter rains was late ($r = –0.84$, $p < 0.05$; Figure A.5). Similarly, the return of geese to Paarl WWTW was earlier when the immediate postbreeding period was relatively dry and later when it was wet ($r = 0.65$, $p < 0.05$), presumably because increased grazing available for the geese after wetter winters enabled them to delay their return to Paarl WWTW. Cape Shoveler tended to disperse earlier than other ducks and showed a strong correlation ($r = –0.63$, $p < 0.05$) with the amount of rainfall during winter (June–August); numbers were higher and birds remained longer at Paarl WWTW during years in which winter rains were lower, than in years in which rainfall was higher and birds dispersed earlier (Figure A.5).

Yellow-billed Duck dispersed later than Cape Shoveler, and this species tended to be present at the wetland in early summer (September–November), particularly when rainfall was higher ($r = –0.81$, $p < 0.001$; Figure 5). In the WRR, both species breed from July to December (Hockey et al. 1989), and their dispersal is most likely linked to their movement to breed at temporary wetlands that were inundated during winter. The timing of the movement is triggered by the extent of rainfall during winter, and this proximate factor stimulates the birds' physiological condition to breed (Winterbottom and Rowan 1962, Halse and Jaensch 1989). Like Cape Shoveler, Red-billed Teal showed a strong correlation ($r = 0.86$, $p < 0.001$) with rainfall during winter (June–August). However, this relationship was related to influxes to, and not dispersal from, Paarl WWTW; increased abundance occurred earlier in years that had wetter winters (Figure A.5).

Increases in the numbers of Little Grebe showed the strongest correlation ($r = 0.83$, $p < 0.001$) with late winter (July–September) rains; more birds arrived during this period when rainfall was higher (Figure A.5). This result suggests that birds move in from surrounding flooded landscapes at a time when most of the ducks have dispersed and probably allows the Little Grebe to occupy an almost vacant 'open water' niche at Paarl WWTW. These results showed that rainfall influences the arrival and/or dispersal of waterfowl at Paarl WWTW and support Maclean's (1976) and Little et al.'s (1995) hypothesis that the timing of breeding in southern African ducks is in response to rainfall.

The link with rainfall variability helps explain both the seasonal occurrence of these species at the works and the interannual variations in occurrence, and demonstrates that environmental cues play an important role in the ecology of waterfowl populations, even at a local scale (Braithwaite and Stewart 1975). Kingsford (1989) and Lawler and Briggs (1991) similarly found that rainfall events initiated breeding and influenced movements in Maned Ducks *Chenonetta jubata* in eastern Australia, and Halse and Jaensch (1989) demonstrated that rainfall acts as the most important proximate cue for waterbird breeding in south-western Australia, an area climatically similar to the WRR.

Colonial breeders

Paarl WWTW supported 13 species of colonially breeding waterbirds, including 10 at the heronry on the islet in pond D (Table A.3). These we divided into three groups, namely cormorants and darter, large wading birds and gulls.

Cormorants and darter

This group comprised three species: White-breasted Cormorant, Reed Cormorant and African Darter. White-breasted Cormorants predominated during winter (Figure A.3) with a maximum of 93 recorded in June 2002; numbers declined between October and January. They initially (from 1988) bred on large *Eucalyptus* spp. trees overhanging pond D on the western shoreline, though some birds used the heronry on the islet in pond D (Y Weiss pers. comm.). The shoreline colony came under progressively increasing human disturbance by wood-cutters from the Mbekweni informal settlement. These birds, together with the birds that attempted to breed in the heronry, moved to pond A where they bred on dead *Pinus* and *Acacia* trees erected by management on an islet in the pond (AJ Williams pers. comm.). The maximum number of concurrent active nests was 40 (Table A.3). Nest sites were occupied throughout the year — probably indicating a shortage of suitable sites in the region — but most breeding occurred between May and July. Winter breeding is characteristic of this species across sub-Saharan Africa (Childress and Bennun 2001, VL Ward and AJ Williams unpubl. data). Reed Cormorants were most abundant from October to January (Figure A.3) with a maximum of 183 recorded in January 1995. Similarly, African Darters occurred mainly from November to February (Figure A.3), with a maximum of 89 recorded in January 2000. Both species bred in trees (*Eucalyptus* spp.) on the islet in pond D between October and February, with with maxima of 49 nests for Reed Cormorants and 26 nests for African Darters (Table A.3). Numbers of both species declined during winter (Figure A.3) indicative of postbreeding dispersal. Reed Cormorants showed significantly downward trends during summer ($r = -0.65$, $p < 0.05$).

Large wading birds

Eight species of waders bred on trees on the islet in pond D (maximum observed nest counts are given): Cattle Egret (132 nests), African Sacred Ibis (63 nests), Black-headed Heron (21 nests), Grey Heron (19 nests), Yellow-billed Egret (12 nests), Little Egret (12 nests), Black-crowned Night-heron (12 nests) and African Spoonbill (8 nests) (Table A.3). The time of nest initiation and breeding was staggered; Black-headed Heron, Grey Heron and African Spoonbill began breeding in July/August, Black-crowned Night-Heron in August/September, Yellow-billed Egret in September, Cattle Egret in October and Little Egret and African Sacred Ibis in November. Breeding for all species was completed by February. Over the 10 years, there were statistically significant increasing trends in numbers for African Spoonbill in summer ($r = 0.77$, $p < 0.01$) and Cattle Egret in winter ($r = 0.74$, $p < 0.05$).

Gulls

The number of Hartlaub's Gulls was highest between July and September, while Grey-headed Gulls peaked between May and December (Figure A.3). Hartlaub's Gulls ($\bar{x} = 274$ birds) were present throughout the year but Grey-headed Gulls ($\bar{x} = 20$ birds) were virtually absent from Paarl WWTW between January and April (Figure A.3). I suggest that the latter are intra-African migrants (see above). Both species showed significant ($r = –0.77$, $p < 0.01$) decreasing trends in winter (Figure 4). The maximum recorded number of Hartlaub's Gull nests in any one year was 10 (Table A.3); a similar number (c. 10 pairs, AJ Williams pers. comm.) have bred at the Wellington WWTW, c. 4 km away. Paarl WWTW is one of the 15 recorded Grey-headed Gull breeding localities in the WRR (Brooke et al. 1999; DMH pers. obs.) with a maximum of 35 nests in 1997 (Table A.3). The Grey-headed Gulls bred near emergent vegetation, whereas the Hartlaub's Gulls bred at more exposed terrestrial sites (DMH pers. obs.). There was no evidence of mixed pairs (i.e. males and females pairing from the two species) as is known for some coastal localities (Sinclair 1977, Williams 1989).

Flamingos

Numbers of Greater and Lesser Flamingos, with maxima of 267 and 1200, respectively, showed wide fluctuations; both species were most abundant from October to November (Figure A.3). The Lesser Flamingo was the only intra-African migrant species for which numbers declined significantly during the study ($r = –0.75$, $p < 0.05$; Figure A.4); no birds were recorded after October 1999. This reflected major changes in pools at the

Wellington leather tannery (8 km north of Paarl WWTW) where *Spirulina*-dominated pools formerly supported feeding Lesser Flamingos (Spottiswoode and Underhill 1994, AJ Williams pers. comm.) that then roosted at Paarl WWTW.

Shorebirds

Five resident species of shorebirds occurred at Paarl WWTW. Black-winged Stilt were most numerous during the winter (Figure A.2) with a maximum count of 527 in May 2001. These winter influxes were probably related to birds congregating after breeding (Table A.3) and rainfall. From March to May increases in abundance were correlated ($r = 0.65$, $p < 0.05$) with the timing of rainfall; birds arrived earlier in years with higher rainfall than in drier autumns. Summer populations remained stable from 1994/95 to 2001/02, but showed signs of a decline from 2002/03 to 2003/04; winter populations fluctuated widely (Figure A.4). Most gathered round the aeration ponds (i.e. pond 1; Figure A.1) where they apparently fed on sewage-fly larvae (Psychodidae), a resource also utilised by White-winged Terns. A maximum of five pairs bred at Paarl WWTW in early summer (Table A.3); decreases in August–September suggested that most stilts dispersed to breed at other ephemeral wetlands at the end of the winter rains.

Blacksmith Lapwing, maximum 327 in January 2004, were most numerous during the summer ($\bar{x} = 80$ birds), peaking in January (Figure A.3). There was a significant upward trend in summer numbers during the study period ($r = 0.72$, $p < 0.05$, Figure A.4). Some bred at Paarl WWTW (maximum four pairs in July/August), but based on the decrease in numbers during winter and their known winter breeding peaks in the WRR (Hockey et al. 1989) it appears as if most birds disperse to alternative feeding and breeding areas during this time. Within the works, the Blacksmith Lapwings preferred the irrigated lawns around the sewage treatment plant. Paarl WWTW is one of only two sites in the Western Cape (the other being Rietvlei Wetland Reserve [Kalejta-Summers et al. 2001a]) that supports more than 300 Blacksmith Lapwings; this figure represents 6% of the estimated provincial population and 13% of the Cape Town metropole population (Table A.4, Figure 1.5, Chapter1). The species has undergone a large range expansion and population increase in the Western Cape since it was first recorded breeding in this province in 1947 (Underhill 2004).

Water Thick-knee ($\bar{x} = 6$ birds, maximum 22 birds in March 2002) were most numerous during early winter (April–June). Their numbers showed significant upward trends in both summer ($r = 0.88$, $p < 0.01$) and winter ($r = 0.77$, $p < 0.01$) during the study period but numbers were small. This increase is probably due to the availability of suitable habitat (bare, stony ground with short grass) at Paarl WWTW. They bred at the works (a nest in September; Table A.3). Three-banded Plover (maximum 85 in September 1995) and Kittlitz's Plover (maximum 75 in April 1999) peaked in abundance during winter (May–August) (Table A.2, Figure A.3). The winter increases suggest immigration from outside of Paarl WWTW. Both species bred in small numbers at the works during spring and summer (Table A.3), but juvenile recruitment did not account for the influxes recorded during winter. Although the abundance of Three-banded Plovers was generally higher in winter, their numbers in winter declined ($r = –0.87$, $p < 0.01$) during the study period (Figure A.4). Numbers of Kittlitz's Plover increased from less than 10 to more than 25 birds between 1998 and 2002 in both summer and winter, but showed declines after winter 2002 (Figure A.4).

Pied Avocets, maximum 218 in December 1997, were most numerous between November and February. Fewer than four birds occurred in other months. None bred at Paarl WWTW but the peak occurrence there followed spring breeding (Hockey et al. 1989). This species showed sporadic peaks during the summers of 1997/98 and 2000/01 with less than 10 birds recorded in other years. This irregular occurrence at Paarl WWTW reflected the known nomadic tendencies of the Pied Avocet in southern Africa, which Tree (1997) ascribed to responses to rainfall patterns across the subcontinent.

Great White Pelican

This species was an irregular visitor, occurring on 33% of the counts. Overall, five pelicans, on average, were recorded during the study with a maximum of 147 recorded during April 2003. Numbers declined after 1997. The mean summer count was 11 from 1994–1997 and decreased to three from 1998–2003; similarly, mean winter counts decreased from seven birds from 1994–1997 to one from 1998–2003. These seasonal declines are probably related to a change in feeding sites. The Western Cape population of Great White Pelicans has doubled from the 1990s to 2000s and this increase seems to be associated with an increased reliance by the pelicans on chicken waste from local poultry farms that are utilised by pig farms (Williams and Borello 1997, De Ponte Machado and Hofmeyr 2004).

Palearctic migrants

Eight species of Palearctic migrants occurred at Paarl WWTW (Tables A.1 and A.2), mainly between late August and April; few birds remained during the austral winter (Figure A.2) (Summers et al. 1995). White-winged Terns formed the majority (93%) of Palearctic migrants. The other Palearctic migrants were shorebirds, which occurred in small numbers (e.g. Little Stint, maximum 157, Curlew Sandpiper, maximum 57; Table A.2).

Numbers of Palearctic migrants peaked in October and in March, coincident with the main arrival and departure months for most Palearctic shorebirds in South Africa (Harrison et al. 1997). The main factor limiting the number of Palearctic shorebirds at Paarl WWTW was the near absence of exposed unvegetated shoreline habitat, which is restricted due to the stone embankments of the maturation ponds. Swanepoel et al. (2006) found a similar trend at Theewaterskloof Dam, a large man-made reservoir situated about 40 km south-east of Paarl WWTW. For White-winged Terns arrival commenced in late August, which is consistent with bird atlas data (Williams and Underhill 1997). Numbers increased rapidly during September, reached their peak in January, and remained high until March (Figure A.3); departure was mainly in April. There was a significant downward trend in the numbers of White-winged Terns ($r = -0.97$, $p < 0.001$, Figure A.4); peak numbers declined from 2796 in January 1995 to 499 in January 2004, a decline of 82%. A possible cause of the lower numbers recorded might be the change from afternoon counts, when more birds sit in roosts, to morning counts when the terns are most active and difficult to count. However, the decrease during the six-year period of afternoon counts was also significant ($r = -0.89$, $p < 0.05$). Kaletja-Summers et al. (2001b) similarly reported a decline in the numbers of White-winged Terns at the Cape Flats WWTW from the 1970s to the 1990s. Declines in breeding success have also been reported in the species' European breeding range (Tomiałojć and van der Winden 1997) and this probably reflects the declines in numbers at Paarl WWTW. These declines reflect the predicted changes in global populations for migrants in relation to climate change. In a review of the impact of global climate change on bird migration, Berthold (1999) predicted that, for long-distance migrants, population declines would first be observed at the southern extremes of the non-breeding ranges.

The data presented here and from Kaletja-Summers et al. (2001b) show that White-winged Tern populations in the Western Cape were consistent with this prediction. The White-winged Tern is therefore a candidate species for intensive monitoring in relation to current global change issues. The peak number (2 796) of White-winged Terns during the study period was the sixth largest on record in South Africa (Coordinated Waterbird Counts, Animal Demography Unit, unpubl. data). In January 1994, before the study period, an estimated 5 100 White-winged Terns were recorded at Paarl WWTW (Y Weiss pers. obs.), which is the second largest count for this species at any locality in South Africa (Coordinated Waterbird Counts, Animal Demography Unit, unpubl. data). Within the Western Cape province and the Cape Town metropole, Paarl WWTW ranked second to the Cape Flats WWTW and together these two sites supported the largest concentrations of White-winged Terns in South Africa (Taylor et al. 1999).

Waterbird Conservation Value (WCV) scores

The monthly WCV scores for Paarl WWTW between May 1994 and April 2004 are shown in Figure A.6. Inter-annual fluctuations were evident and no pattern was discernable; although peaks tended to occur more in winter (June–July) than in summer. No scores > 10 were observed. The median summer and winter scores were 2.6 and 3.0 respectively. The month with the highest average score was May (6.2).

Nine species made significant contributions to the WCV score (Figure A.6). Of these, Hartlaub's Gull and Black-winged Stilt had the largest scores during the study period; 3.5 and 2.3 respectively. Pied Avocet occurrence was erratic and only scored high in December 1997 with a value of 1.15. Lesser Flamingo was only abundant from 1994–1999; it scored 2.0 in October 1995. All other species had maximum scores less than 1 during the study period and made negligible contributions to the WCV score.

General discussion

Variation in occurrence of resident species

The variation in abundance and occurrence exhibited by certain species reflected the complexity of their status in the WRR. For example, flamingos breeding in the WRR is an exceptional event (see Uys et al. 1963) while others (e.g. Black-necked Grebe, Southern Pochard, Pied Avocet and Grey-headed Gull) breed mainly in the summer-rainfall areas (Harrison et al. 1997). Great Crested Grebe, Cape Shoveler and Red-knobbed Coot are considered mainly resident in the WRR and have substantial breeding populations in this region (Hockey et al. 1989, Ashkenazi 2001). However, their seasonal pattern of occurrence at Paarl WWTW suggests that they move seasonally out of the WRR. Confusingly, interregional movements by these species (Great-crested Grebe, Cape Shoveler and Red-knobbed Coot), while annual in some (e.g. Southern Pochard), vary considerably in relation to wetland conditions in either the winter- and/or summer-rainfall areas. When winter rains are low in the WRR there are limited resources for waterbirds, many of which may then undertake additional local movements in search of suitable habitat. Precipitation in summer-rainfall areas, especially semi-arid regions, varies in timing and amount (Cowling et al. 1997). These variations affect the numbers of birds that breed successfully and therefore impact the annual extent of interregional movement. In drought periods, when most pans in the summer-rainfall areas fail to flood, Allan and Underhill (1999) hypothesised that many waterbirds remain in the WRR. This is known to be the case for the Greater Flamingo, for which large numbers occur at Langebaan Lagoon in summer when there are droughts in the interior (Underhill 1987).

Food availability

Like most wastewater treatment works, the ponds at Paarl WWTW are nutrient rich and provide favourable breeding and feeding conditions for fish and insects, and growth of aquatic vegetation. Detailed studies of food abundance and availability have not been carried out, but these attributes are probably the most important factors driving the occurrence and abundance of waterbirds at the works. The aeration ponds support large numbers of sewage flies (Psychodidae), which breed abundantly in the ponds (B Gale pers. comm.). Egg-laying of these flies may occur throughout the year but is most prolific during summer (PEI Pest Control 2005). The fly larvae feed on benthic detritus and then pupate. The oil-rich pupae float to the surface and then form a rich food resource for invertebrate-feeding birds, notably White-winged Terns, which pick them off the surface whilst in flight, Hartlaub's and Grey-headed Gulls, which feed on them whilst swimming, and Black-winged Stilts, which pick off those within reach of the pond's edge. The availability of sewage fly pupae is probably the main attraction of Paarl WWTW for the gulls and White-winged Terns.

For fish-eating species (cormorants, darter, pelicans, herons), Tilapia *Oreochromis mossambicus* are probably more frequently taken due to their smaller size (±15–20 cm), compared with carp *Cyprinus* spp., which have been observed to reach lengths of up to 60 cm (pers. obs.). Fish abundance, particularly carp, has generally increased in the ponds (C Morkel pers. comm.), and this might have reduced the availability of algae and diatoms, favourite foods of Lesser Flamingos. The absence of Lesser Flamingos after 1999 might be linked to such changes; similar patterns were described by Kaletja-Summers et al. (2001b) for the Strandfontein Sewage Works.

The conservation importance of Paarl Waste Water Treatment Works for waterbirds

Paarl WWTW supports a number of waterbirds that are important relative to respective population levels and are therefore of conservation importance (Table A.4). The most important of these is the Hartlaub's Gull for which Paarl WWTW supported 1% of the estimated global population on 28% of counts across the decade. Numbers of an additional four species — Maccoa Duck, Lesser Flamingo, Black-winged Stilt and Pied Avocet —reached levels that represented more than 1% of the estimated southern

African populations (Wetlands International 2006). Paarl WWTW also supported provincially important populations of Grey-headed Gull and White-faced Duck (Table A.4). In terms of species maxima, Paarl WWTW ranks as the fourth most important site for waterbird abundance within Cape Town metropole and 14th among Western Cape wetlands, where all major wetlands are surveyed (Table A.5). Four species of Red Data waterbirds occurred at the wetland during the decade. These were the 'vulnerable' African Marsh Harrier and the 'near-threatened' Great White Pelican, and Greater and Lesser Flamingos (Barnes 2000); the last species is also globally threatened. There is suitable habitat for African Marsh Harriers at Paarl WWTW but evidently not on a sufficient scale to sustain a regular population, and this species has decreased during the 10-year study period. Great White Pelicans use Paarl WWTW as an occasional roost but their occurrence there is erratic.

The two flamingo species formerly occurred more frequently at Paarl WWTW, but numbers have fallen and occurrence is more erratic since the closure of a *Spirulina*-producing pond at a tannery in Wellington (4 km away), which formerly provided a food resource for flamingos that then roosted at Paarl WWTW. In November 1997 (Y Weiss pers. comm.) 30 nest mounds were constructed by Lesser Flamingos on the island in front of the bird hide at pond B. This is the furthest south that Lesser Flamingos have been recorded nest building in southern Africa (Williams and Velásquez 1997). Wetland connectivity is an important landscape consideration for most waterbirds (Haig et al. 1998) as many species move around locally or regionally in search of optimal feeding and/or breeding sites. In the metropolitan context, exchange and movement between Paarl WWTW and other urban sites can therefore be assumed to take place. Recent colour-ringing studies have shown that African Sacred Ibis and African Spoonbill move between Paarl WWTW and other wetlands around Cape Town (DMH unpubl. data), providing evidence of exchange of birds (and genetic material) between local populations and inter-connectivity between sites within the Cape Town metropole. To what extent these and other waterbirds move between these sites requires further investigation; additional ringing studies will be needed to assess this.

Importance of Paarl Waste Water Treatment Works as a breeding site

Paarl WWTW is important within the Cape Town metropole as a breeding locality for a number of waterbirds. In particular, the >300 nests in the 'heronry' represent the fourth largest breeding locality in the metropole after Robben Island (Underhill et al. 2007), Rondevlei (D Gibbs pers. comm.) and Intaka Island (Harrison 2005). This study recorded the largest number of nests for Hartlaub's and Grey-headed Gull in the WRR, and highlights the importance of Paarl WWTW as a major inland breeding site for both species in the region. Paarl WWTW was the first recorded inland breeding locality for the Hartlaub's Gull, which was previously known to be an exclusive coastal breeding species (Crawford 1997). Grey-headed Gulls are generally more uncommon than Hartlaub's Gulls in the WRR; the breeding population at Paarl WWTW could therefore act as an important recruitment site for this species in the region. No interbreeding between Hartlaub's and Grey-headed gulls has been recorded at Paarl WWTW, although hybridization between these species has been reported from elsewhere in the WRR (Sinclair 1977,Williams 1989).

It is important that the breeding status of waterbirds at the works be sustained into the future. During 2004 some of the large trees on the island in Pond D were beginning to collapse (pers. obs.). To counteract natural degradation on the island we suggest erection of one or a few artificial breeding 'platforms' of the type used successfully at Intaka Island, Cape Town (Harrison et al. 2001, Harrison 2005, Harrison et al. 2010).

Conservation priorities

The decade of counting has shown that Paarl WWTW is a valuable wetland for resident southern African waterbirds, including local migrants such as Greater and Lesser Flamingos. Its importance is through its provision of a dry-season refuge, particularly for resident waterfowl species, when most ephemeral wetlands dry out. Man-made or artificially created wetlands have become increasingly important to waterfowl, particularly as places of refuge, as natural wetlands have disappeared (Owen and Black 1990).

In addition, Paarl WWTW provides safe breeding sites for colonial breeding species. The diversity of birds supported and attractive viewing conditions has made the treatment works a popular bird-watching locality (Petersen and Tripp 1995, Weiss 1996, 2004). As an urban wetland, Paarl WWTW is subject to numerous socioeconomic impacts. During the decade of counting, the Mbekweni informal settlement developed just to the east of the railway line (Figure A.1). People from this settlement have easy access to Paarl WWTW via an underpass. Although there have been incidents of vandalism at the works and illegal fishing occurs in some of the ponds, people from the settlement do not seem to pose any major disturbance to the waterbirds. Changes in hydrology (e.g. the draining and refilling of pond 3) and wastewater treatment have had greater impacts on waterbird populations. This supports findings by Velásquez (1992) who found that habitat changes and water-level fluctuations at artificial salt-pans were more important in determining occurrence and abundance of shorebirds than human disturbance. The numbers of nine species (Hartlaub's Gull, Maccoa Duck, Black-winged Stilt, Lesser Flamingo, White-breasted Cormorant, Pied Avocet, Cape Shoveler, Black-necked Grebe and Great White Pelican) qualify the site for Ramsar and Important Bird Area (IBA) status (Table A.4, Wetlands International 2006). These global conservation initiatives aim to prioritise important global and regional wetland and bird conservation sites for biodiversity conservation (Barnes 1998, Fishpool and Evans 2001). The designation of Paarl WWTW as a Ramsar and/or IBA site will improve the conservation status of the site and secure the long-term preservation of the wetland for southern African waterbirds.

Management actions and recommendations

Currently, Paarl WWTW Sewage Works is administered by the Civil Engineering Services Department of the Drakenstein Municipality (Weiss 2004), which oversees management and operation of the sewage works. An advisory committee was established in 1994 to assist with the management of the bird sanctuary area. The committee recommended initiation of monthly counting and drew up a management plan for the Bird Sanctuary (maturation ponds) area. Actions since 1994 have included: the erection of four bird hides and an information kiosk; provision of rafts to encourage bird breeding (failed); erection of dead pine trees (successfully used for breeding by White-breasted Cormorants); the creation of a breeding embankment for kingfishers (successful but subsequently damaged by a photographer); and a bird ringing programme (Weiss 1996, Harebottle 2005, G Scholtz pers. comm.).

Other issues that need to be considered in relation to management of the site include burning (incorporating reedbed management, Worrall et al. 1997), impact of human disturbance, occurrence and impact of invasive aquatic plants (e.g. water lettuce *Pistia stratiotes*) and development of the heronry. At present, the bird sanctuary area is not formally protected and, given the area's demonstrated conservation value, greater legal protection (e.g. nature reserve status) is recommended to secure the long-term future of the sanctuary. Waterbirds are currently monitored monthly by members of the Paarl WWTW Monitoring Group. In addition, water-level and quality, aquatic and emergent vegetation and invertebrate and fish populations should be monitored; manipulation of pond water-levels needs consideration as a management option as this could attract more wading and shore birds (Velásquez 1992, Colwell and Taft 2000). These factors are important because they affect habitat changes and food availability, which aid in interpreting and understanding changes in waterbird abundance and occurrence.

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Table A.1 Maximum count of waterbird species recorded in < 25% of the 120 monthly surveys at Paarl Waste Water Treatment Works from May 1994–April 2004.

Species	Max. count	Date(s) of maximum count
Fulvous Duck	1	Oct./Nov. 1998, Nov. 2001
South African Shelduck	11	Oct. 1997
Hottentot Teal	2	Jun. 1998
Comb Duck	2	Oct. 1994, Oct./Nov. 1999
Mallard	2	Apr. 2001
Great Egret	1	May 1997, Mar. 2003
Goliath Heron	1	Mar. 1999, Jun./Aug. 1999
Squacco Heron	1	Jun./Aug. 1999, Jul. 2003
Hamerkop	1	May 1994, Mar. 1995, Aug. 1995, Apr 1996, Oct.1997, Jun. 1999, Aug. 2000
African Marsh Harrier	2	Jan. 1996, Jun. 1998, May 1999, Apr./May 2004
Osprey	1	Jan. 2000
African Rail	1	Apr. 1995, Mar./Apr. 2001, Jun. 2001, Mar. 2002, Apr. 2004
African Crake	3	Sep. 1997
American Purple Gallinule	1	Jul./Aug. 2000, Nov./Dec. 2000
African Jacana	1	Oct. 1996, Sep. 2001,
Ruff	4	Mar. 2000
Marsh Sandpiper	3	Mar. 1995, Nov. 1995
Greater Painted Snipe	5	Jan. 2003
Kelp Gull	21	Jul. 1997
Whiskered Tern	2	Jun. 2001

Table A.2 Seasonal abundance of 55 waterbird species that occurred in > 25% of all counts at Paarl Waste Water Treatment Works from May 1994 to April 2004. Species grouped according to regional guilds and sorted in descending order of frequency of occurrence and overall mean abundance.

Species	Summer		Winter	
	Mean ± S.D.	Min-Max[1]	Mean ± S.D.	Min-Max[1]
Residents				
Waterfowl				
Yellow-billed Duck	31.3 ± 6.7	2–121	30.3 ± 14.3	0-116
Egyptian Goose	463.9 ± 252	0–1341	216.2 ± 252.3	16-1052
Cape Teal	21.5 ± 6.7	0–83	22.6 ± 7.6	2–85
Red-billed Teal	25.2 ± 5.7	0–65	33.5 ± 11.3	2–151
Cape Shoveler	58.4 ± 30.7	0–237	41.6 ± 14.7	0–138
White–backed Duck	2.2 ± 1.5	0–21	1.1 ± 1.4	0–21
Maccoa Duck	10.9 ± 3.9	0–71	13.5 ± 9.3	0–235
African Black Duck	2.4 ± 0.7	0–9	3.6 ± 1.2	0–9
Spur–winged Goose	11.9 ± 12.3	0–118	1.9 ± 2.3	0–31
Southern Pochard	10.9 ± 13.4	0–148	11.1 ± 7.8	0–50
Common Moorhen	35.5 ± 13.3	8–163	39.1 ± 9.2	7–105
Red–knobbed Coot	116.4 ± 35.4	24–296	93.4 ± 9.4	32–243
Little Grebe	96.9 ± 67.5	19–334	162.1 ± 90.1	0–433
Black–necked Grebe	4.9 ± 3.5	0–46	19.3 ± 12.6	0–131
Great Crested Grebe	1.6 ± 0.6	0–5	0.5 ± 0.4	0–7
White–faced Duck	5 ± 1.8	0–33	6.4 ± 3.7	0–58
Sub–total	**898.2 ± 261.3**	**284–1747**	**695.6 ± 326.3**	**204–1853**
Cormorants and darter				
Reed Cormorant	35.7 ± 20.2	0–183	15.9 ± 6.5	3–73
African Darter	36.9 ± 10.9	0–89	14.3 ± 5.2	0–41
White–breasted Cormorant	27.1 ± 8.5	2–74	45.9 ± 13.5	10–93
Sub–total	**99.5 ± 18.5**	**4-272**	**76 ± 6.6**	**25-153**
Pelicans				
Great White Pelican	6.9 ± 4.8	0–52	6.2 ± 9.9	0–147
Flamingos				
Greater Flamingo	31.3 ± 24.2	0–267	17.7 ± 11.7	0–172
Lesser Flamingo	114.6 ± 97.2	0–1200	32.3 ± 42.3	0–751
Sub–total	**145.8 ± 121.3**	**0–1210**	**50 ± 53.9**	**0–751**
Waders				
Pied Avocet	8.8 ± 8.4	0–218	2.2 ± 1.3	0–15
African Sacred Ibis	131.6 ± 21.2	23–673	67.7 ± 12.4	0–195
Hadeda Ibis	3.1 ± 1.3	0–17	6.4 ± 2.4	0–25
Water Thick–knee	4.3 ± 1.1	0–22	6.7 ± 1.4	0–21
African Spoonbill	2.5 ± 2.7	0–44	3.4 ± 1.1	0–23
Little Bittern	0.4 ± 0.2	0–2	0.4 ± 0.2	0–2
Black–crowned Night–heron	9.8 ± 5.4	0–44	13.3 ± 5.3	0–42
Grey Heron	8.4 ± 4.8	0–27	9.5 ± 5.5	0–35
Black–headed Heron	4.1 ± 1.8	0–24	5.1 ± 2.9	0–35
Purple Heron	0.7 ± 0.5	0–6	0.9 ± 0.5	0–4
Little Egret	1.9 ± 1.1	0–16	1.4 ± 0.6	0–8
Yellow–billed Egret	1.1 ± 0.8	0–7	1.3 ± 0.9	0–19
Glossy Ibis	0.4 ± 0.3	0–4	1.3 ± 0.7	0–9
Cattle Egret	110.4 ± 37.3	29–270	74.1 ± 23.8	14–218
Sub–total	**578.4 ± 42.2**	**100–944**	**293 ± 20.7**	**62–379**

Table A.2 contd

Species	Summer		Winter	
	Mean ± S.D.	Min-Max[1]	Mean ± S.D.	Min-Max[1]
Raptors				
African Fish Eagle	0.5 ± 0.4	0–2	0.4 ± 0.4	0–3
Rallids				
African Purple Gallinule	2.9 ± 0.5	0–10	3 ± 0.9	0–10
Black Crake	0.8 ± 0.3	0–4	1.4 ± 0.8	0–10
Sub–total	**3.7 ± 0.7**	**0–11**	**4.3 ± 1.6**	**0–16**
Shorebirds				
Blacksmith Plover	89.3 ± 20.9	16–327	43 ± 12.2	0–113
Black–winged Stilt	75.3 ± 13.1	0–232	190.7 ± 70.5	0–527
Three–banded Plover	15.9 ± 4.6	0–39	23.2 ± 11.8	0–85
Kittlitz's Plover	12.2 ± 3.9	0–44	22.8 ± 3.8	0–75
African Snipe	0.9 ± 0.9	0–13	1.6 ± 1.8	0–12
Sub–total	**193.4 ± 23.1**	**42–398**	**281.2 ± 84.9**	**70–605**
Gulls				
Hartlaub's Gull	250.4 ± 39.1	11–689	297.6 ± 116.5	0–1058
Grey–headed Gull	16.3 ± 11.9	0–273	23.7 ± 7.3	0–130
Sub–total	**266.7 ± 49.5**	**11–826**	**321.3 ± 121.1**	**0–1188**
Palearctic migrants				
Shorebirds				
Common Sandpiper	7.5 ± 2.3	0–32	1.8 ± 2.7	0–20
Little Stint	50.4 ± 10.8	0–157	7.1 ± 11.3	0–100
Common Greenshank	0.9 ± 0.4	0–3	0.2 ± 0.2	0–3
Wood Sandpiper	1.1 ± 0.9	0–15	0.2 ± 0.2	0–2
Curlew Sandpiper	2.6 ± 2.6	0–57	0.2 ± 0.2	0–3
Sub–total	**62.3 ± 10.5**	**0–185**	**9.3 ± 12.5**	**0–104**
Terns				
White–winged Tern	**858.2 ± 386.5**	**4–2796**	**13.9 ± 20**	**0–123**
Total residents	**2047.2 ± 143.8**	**787–3064**	**1677.7 ± 247.9**	**783–2710**
Total Palearctic migrants	**920.4 ± 379.1**	**22–2913**	**23.2 ± 32.2**	**0–177**
Overall total	**2967.6 ± 504.4**	**809–5269**	**1700.9 ± 250.5**	**787–2728**

[1] The sub-total values here reflect the minimum/ maximum number for the group profile as a whole and not the sum of individual minima/maxima for each species which would represent estimated min./max. carrying capacity and not actual min./max. numbers reflected by the dataset

Table A.3 Maximum number of pairs of 33 solitary and colonially breeding waterbirds recorded breeding at Paarl Waste Water Treatment Works from May 1994 to April 2004. Records based on confirmed sightings of eggs and/or chicks. For selected species, the month(s) in which the maximum number of pairs was recorded in any given year is given in parentheses. Species order based on month when first rains begin (i.e. April). WRR = Winter rainfall region.

Solitary breeders			Colonial breeders		
Species	Max. pairs	Breeding season in WRR[1]	Species	Max. pairs	Breeding season in WRR[1]
Red-billed Teal	1 (Apr)	Aug–Dec	Grey-headed Gull	35 (May)	Apr
Black Crake	1 (Apr)	Mar–Dec	Hartlaub's Gull	10 (Jun)	Feb–Sep
Blacksmith Lapwing	4 (Jul/Aug)	Jul–Dec	**Pond A heronry**		
Southern Pochard	1 (Sep)	Jul–Mar	White-breasted Cormorant	40 (May)	Aug–Apr
Cape Shoveler	2 (Sep/Oct)	Jul–Dec	**Pond D heronry**		
Egyptian Goose	5 (Sep)	Jun–Feb	Black-headed Heron	21 (Jul)	Jul–Jan
Water Thick-knee	1 (Sep)	Sep–Dec	Black-crowned Night–Heron	12 (Aug)	Aug–Jan
Black-winged Stilt	5 (Sep)	Aug–Dec	African Spoonbill	8 (Aug)	Jul–Dec
Kittlitz's Plover	12 (Sep)	Aug–Feb	Grey Heron	19 (Aug)	Jul–Jan
Three-banded Plover	1 (Sep;Feb)	Aug–Mar	Yellow-billed Egret	12 (Sep)	Aug–Dec
Yellow-billed Duck	2 (Oct/Nov)	Jul–Dec	Cattle Egret	132 (Oct)	Aug–Feb
African Purple Gallinule	3 (Nov)	Aug–Feb	Reed Cormorant	49 (Oct)	Jul–Jan
Common Moorhen	3 (Nov)	Aug–Mar	African Sacred Ibis	63 (Nov)	Aug–Jan
Red-knobbed Coot	9 (Nov)	Jul–Feb	African Darter	26 (Nov)	Aug–Feb
Malachite Kingfisher	1 (Nov)	Aug–Dec	Little Egret	12 (Nov)	Aug–Dec
Cape Teal	1 (Nov)	Aug–Apr			
Great Crested Grebe	1 (Dec)	Aug–Mar			
Maccoa Duck	2 (Dec)	Oct–Apr			
Little Grebe	4 (Jan)	Sep–Mar			
White-faced Duck	1 (Jan/Feb)	Dec–Feb			
Total	**118**		**Total**	**439**	
Overall total: 557					

[1] Dates sourced from Hockey et al. (1989).

Table A.4 Species of conservation importance at Paarl Waste Water Treatment Works based on maximum counts from a 120 surveys from May 1994 to April 2004. Species are sorted in descending order of global, regional and provincial importance. Only species with estimated proportions of more than 5% of Western Cape and/or Cape Town metropole populations are shown. Number in parentheses represents the number of times the threshold level was reached and/or surpassed. Species in bold are included in the South African Red Data book (Barnes 2000). NT = Near–threatened, V = Vulnerable.

Species	Max. count	Population level			
		Global[1] (Ramsar 1%)	Sub–regional[2] (IBA 0.5%)	Western Cape[3]	Cape Town metropole[3]
Hartlaub's Gull	1058	3.5% (43)	7.0% (78)	6%	10%
Maccoa Duck	235	2.4% (1)	4.7% (4)	14%	31%
Black-winged Stilt	527	2.3% (18)	4.6% (35)	7%	24%
Lesser Flamingo (NT)	1200	2% (5)	4% (9)	13%	50%
White-breasted Cormorant	163	1.4% (1)	2.7% (15)	<5%	6%
Pied Avocet	218	1.1% (1)	–	2%	6%
Cape Shoveler	333	–	2.2% (5)	3%	8%
Black-necked Grebe	131	_	1.8 (4)	<5%	10%
Great White Pelican (NT)	147	–	1.47% (1)	<5%	12%
Grey-headed Gull	273	–	–	29%	77%
White-faced Duck	58	–	–	19%	30%
White-winged Tern	2796	–	–	15%	18%
Black-crowned Night-Heron	44	–	–	8%	16%
Common Moorhen	163	–	–	7%	14%
African Sacred Ibis	673	–	–	7%	14%
Water Thick-knee	22	–	–	7%	20%
Yellow-billed Egret	19	–	–	6%	13%
Blacksmith Lapwing	327	–	–	6%	13%
Little Grebe	433	–	–	5%	13%
Common Sandpiper	32	–	–	–	23%
Three-banded Plover	85	–	–	–	21%
Egyptian Goose	1341	–	–	–	15%
Hadeda Ibis	25	–	–	–	12%*
African Spoonbill	44	–	–	–	12%
Wood Sandpiper	15	–	–	–	11%
Reed Cormorant	183	–	–	–	10%
African Marsh Harrier (V)	2	–	–	–	5%

[1] Figures represent the percentage of the estimated global* or Southern African# population based on the maximum count. Number in parentheses represents the number of counts which met or surpassed the 1% threshold level. Calculated from Wetlands International (2006).

[2] Figures represent the number of counts which met or surpassed the Sub-regional IBA level (0.5% threshold) for southern Africa (Barnes 1998) but did not surpass the 1% global threshold level.

[3] Value represents the percentage of the estimated provincial population and based on the maximum count. Estimates sourced and calculated from Coordinated Waterbird Counts, Avian Demography Unit, unpublished data (2006)

Table A.5 Ranking of 30 wetland sites in the Western Cape Province during summer (S) and winter (W) based on sum of maximum counts for each species from Coordinated Waterbird Counts (unpublished data, University of Cape Town). Data based on six-monthly data only (i.e. mid-summer and mi-winter surveys only). Where additional published sources are available these are mentioned but only as additional information. Sites in bold refer to the sites discussed in this thesis.

Rank	Locality	S	W	Source/Remarks
1	Langebaan Lagoon	90173	34772	
2	Strandfontein WWTW*	89122	33740	104 340 based on Kaletja–Summers 2001[1]
3	**De Hoop Vlei**	42825	46593	this thesis, based on monthly counts
4	Berg River Estuary	44600	38803	
5	**Rocher Pan**	35846	17874	this thesis, based on monthly counts
6	**Bot River Estuary**	32127	27998	this thesis, based on monthly counts
7	Swartvlei Estuarine System	12352	19227	
8	Rietvlei *	15567	8337	
9	Verlorenvlei	15509	7376	
10	Wilderness Estuarine System	13850	13850	
11	Wadrif Saltpan	13457	23330	
12	Jakkalsvlei	12825	5454	
13	Theewaterskloof Dam	12130	3917	Swanepoel et al. 2007; updated to include data until 2009
14	**Paarl WWTW***	11023	7067	this thesis, also Harebottle et al. 2008
15	Voelvlei Dam	10399	2105	
16	Knysna Estuary	10334	5249	
17	Klein River Estuary	8859	9764	Harebottle 2010
18	Radyn Dam	8525	1693	
19	**Droëvlei Dam**	7444	4857	this thesis, based on monthly counts
20	Heuningnes River Estuary	7237	1213	
21	Olifants River Mouth	4425	4115	
22	Zandvlei Estuary*	3999	3610	
23	Keurbooms River Estuary	3691	2787	
24	Wildevoelvlei*	3565	2834	
25	Breede River Estuary	3518	1811	
26	Beaufort West WWTW	3214	1869	
27	Rondevlei*	3210	2505	
28	Diep River Estuary*	2975	1541	
29	Macasser WWTW*	1662	1178	
30	Great Brak Estuary	1108	545	

[1] these analyses based on monthly seasonal means

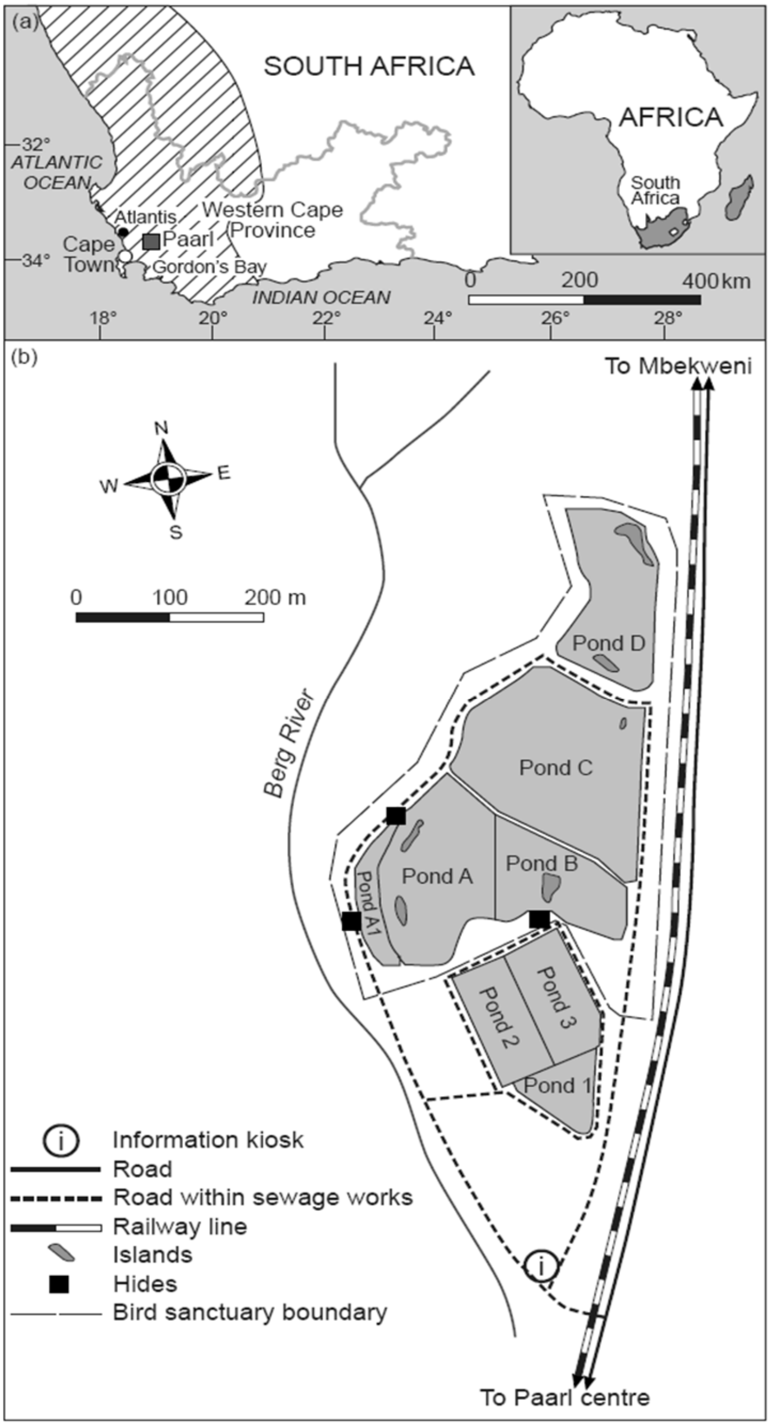


Figure A.1 Maps showing (a) the Western Cape Province, South Africa and the location of Paarl (inset shows the winter-rainfall region [shaded] based on Cowling et al. 1997), and (b) the detailed layout of Paarl Waste Water Treatment Works showing the boundaries of the Paarl Bird Sanctuary and the distribution of the ponds.

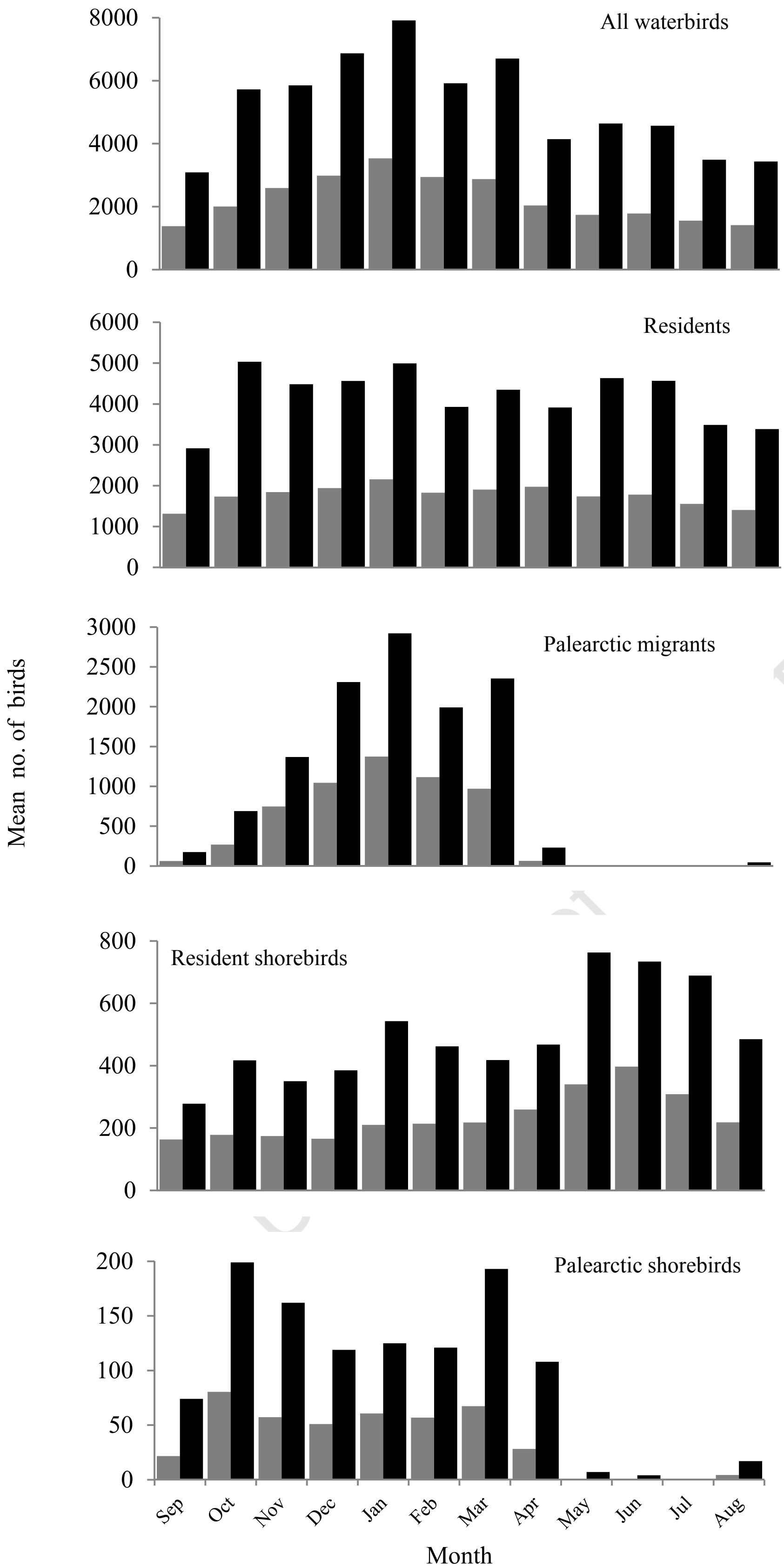


Figure A.2 Mean (grey bars) and maximum (black bars) monthly number of all waterbirds, residents and Palearctic migrants at Paarl Waste Water Treatment Works from May 1994 to April 2004.

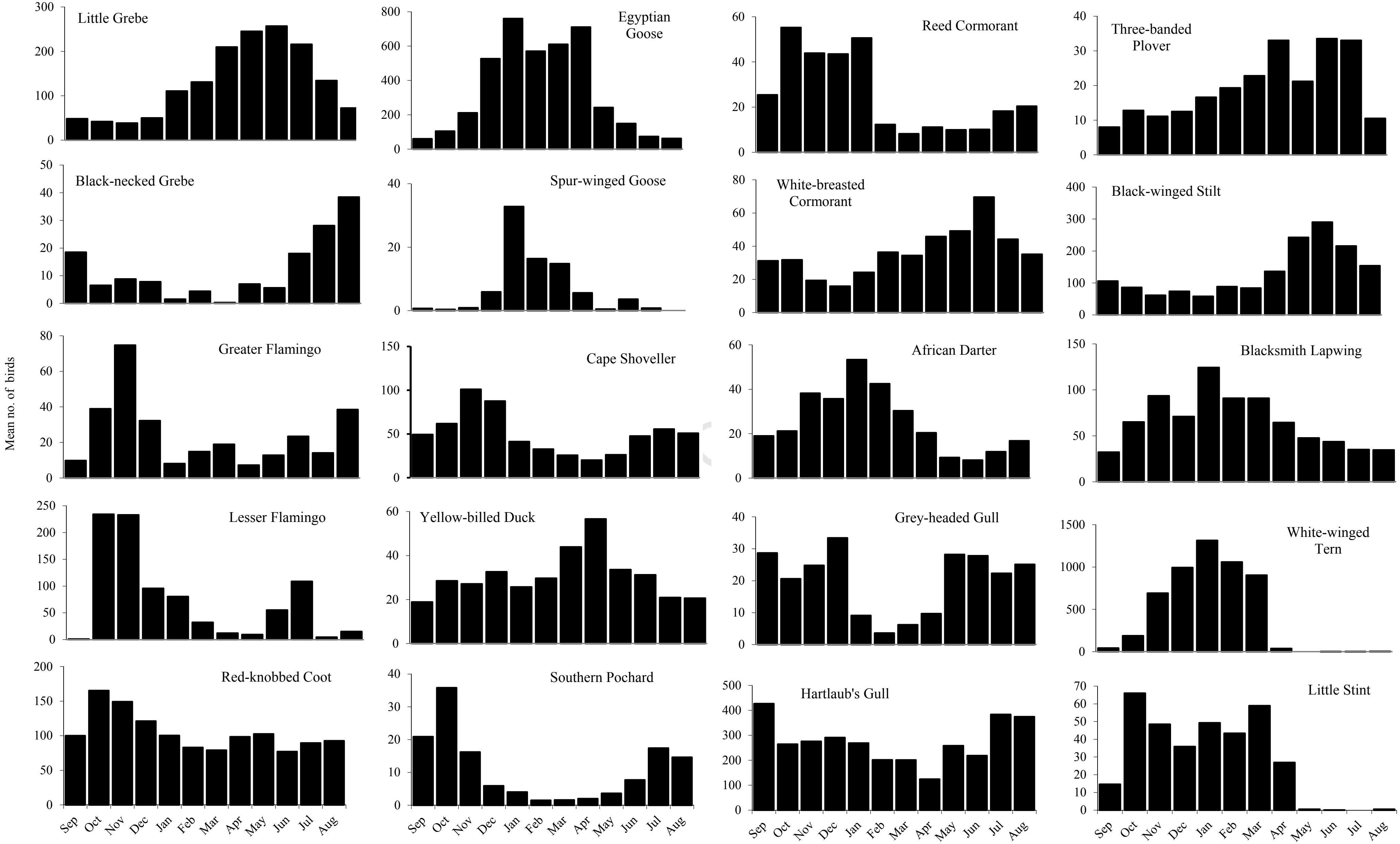


Figure A.3 Mean monthly abundance of 25 waterbirds at Paarl Bird Sanctuary from May 1994–April 2004.

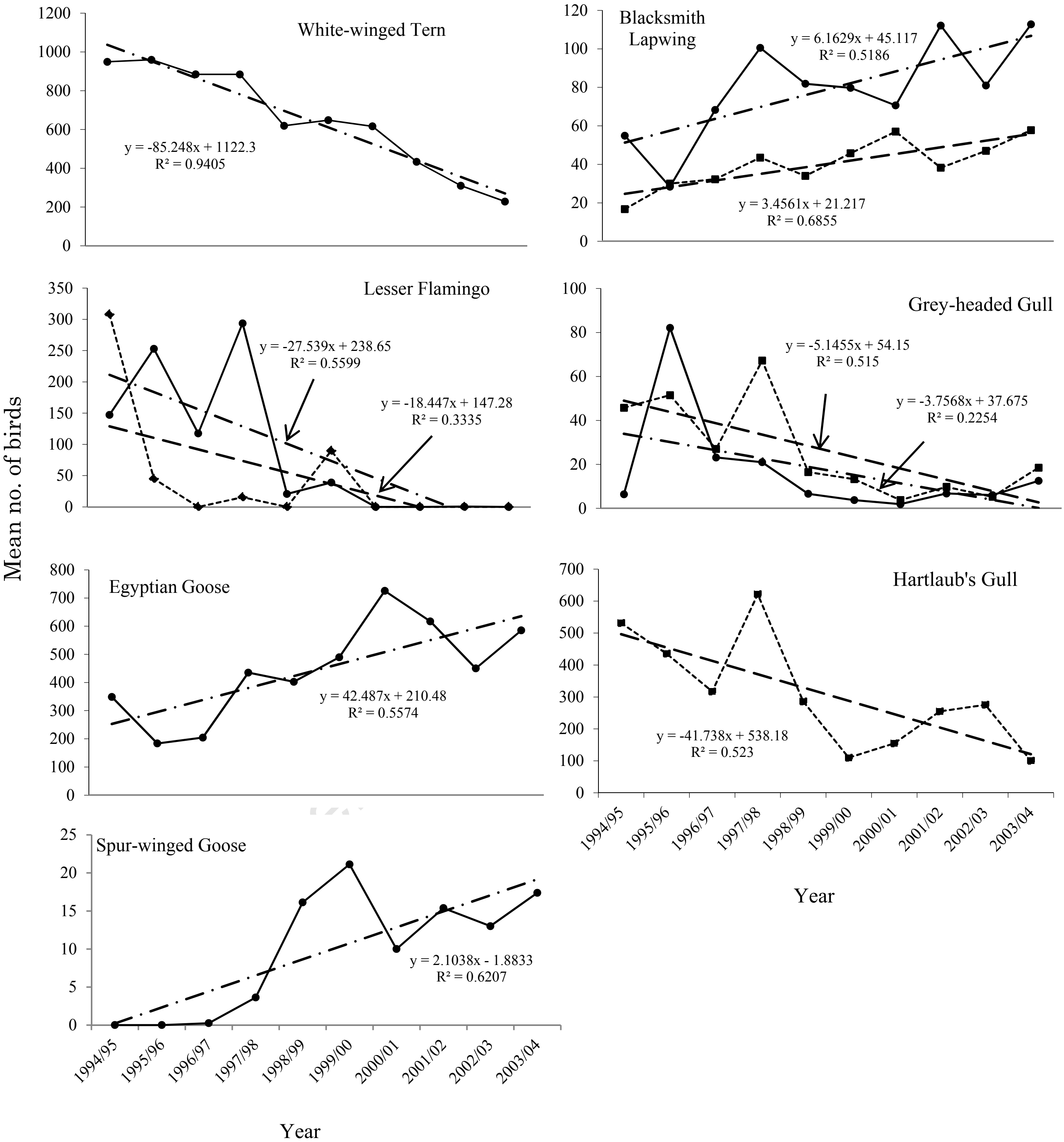


Figure A.4 Mean annual summer (black circle) and/or winter (black square) population trends of seven waterbird species at Paarl Waste Water Treatment Works from April 1994 to May 2004. Regression lines are shown for summer (–·–) and winter (– –) where appropriate.

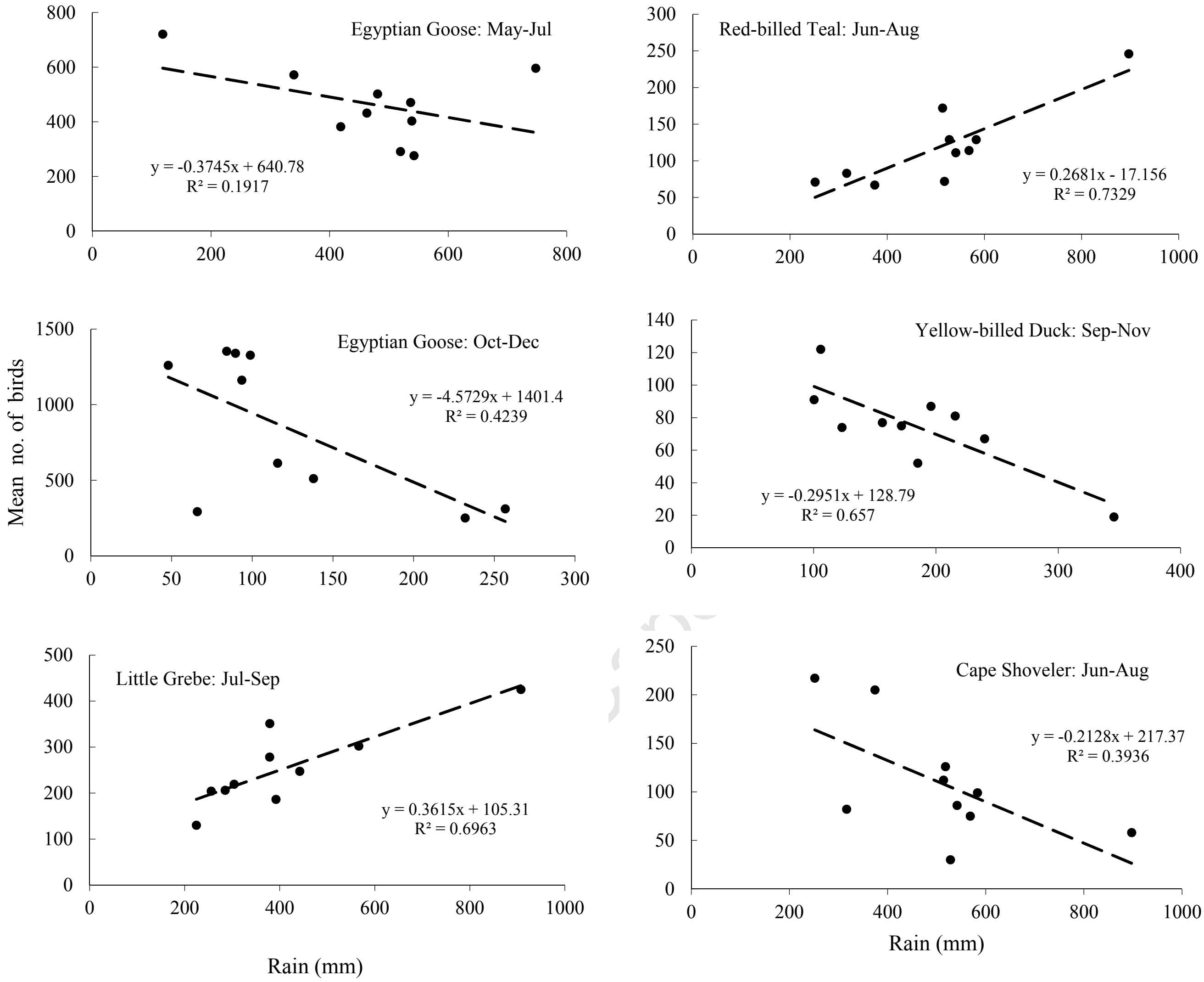


Figure A.5 Relationship between rainfall and abundance of selected waterfowl at Paarl Waste Water Treatment Works. The figures represent cumulative totals for the periods indicated. Refer to text for *r* values.

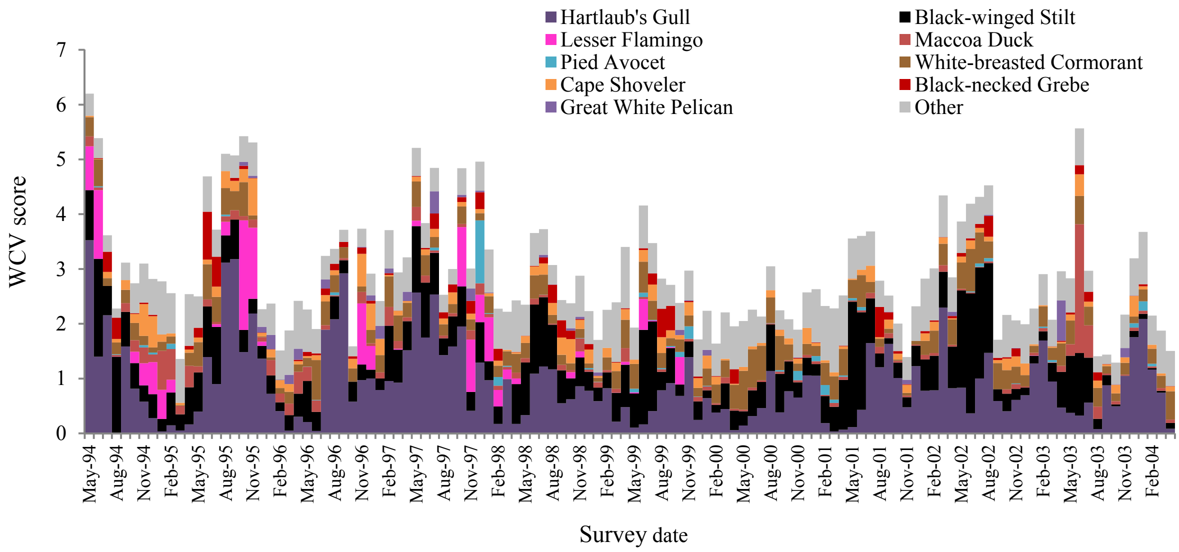
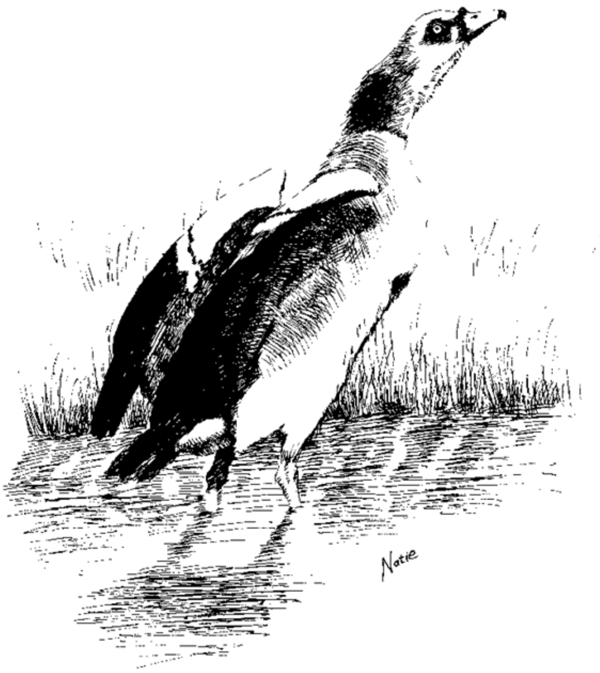


Figure A.6 Monthly Waterbird Conservation Value (WCV) scores for Paarl WWTW from May 1994–April 2004. Relative contributions of species reaching 0.5% or 1% threshold levels are shown.

Appendix B

Long-term waterbird trends at a South African farm dam in the winter rainfall region: Droëvlei Dam, Western Cape, 1982–2006



Abstract

The total extent of water in the thousands of farm dams in the winter rainfall region of southern Africa is now far greater than that in all the region's natural permanent wetlands yet the role played by farm dams in terms of waterbird support is poorly known. Waterbird abundance and seasonality was therefore assessed at Droëvlei Dam, a 14 ha farm dam near Malmesbury, South Africa for two periods: 1982–1990 and 1995–2006. Surveys during 1982–1990 recorded 50 species of waterbirds with mean summer counts of 1 935 ± 973 birds and mean winter counts of 791.8 ± 476.4 birds. The 1995–2006 surveys recorded 47 species; mean summer counts of 2 245 ± 1 847 birds revealed a five-fold difference compared with winter counts 437 ± 533 birds. Overall abundance was strongly seasonal with higher numbers in summer than winter. Waterfowl dominated the waterbird community during both periods (46% and 69% respectively) and used the site as a breeding and moulting site, and dry season refuge. Egyptian Goose was the most abundant species which also showed a 57% increase in numbers at the dam during the two census periods. A total of three species surpassed the global 1% threshold levels during both census periods: Maccoa Duck, Pied Avocet and Great White Pelican. The role of farm dams are discussed in a general context and aspects relating to landowner management are discussed in relation to conservation of wetlands on private land.

Plate B.1 Droëvlei Dam looking west from the main road (R304). Photo: DM Harebottle.

Introduction

In a country with highly seasonal and unpredictable rainfall, South Africa has few permanent natural inland waterbodies (Cowan 1995, Davies and Day 1998, Taylor et al. 1999). Almost all permanent waterbodies are artificial impoundments or large reservoirs (Cowan and van Riet 1998, Davidson and Delany 2000). There are over 500 medium-large reservoirs (i.e. with a wall equal to or higher than 15 m from base to crest and usually kilometres long) in South Africa (Davies and Day 1998) constructed by 1986, most of which provide potable water to towns and cities, and farming communities. Their total capacity amounts to 52% of annual run-off (Davidson and Delany 2000). With a large agricultural sector in South Africa, many private farm dams have been built to irrigate croplands and/or provide drinking water to stock. These smaller impoundments (a few hectares in size and with walls usually less than 5 m in height) possibly number tens of thousands but it is unclear as to their exact number (Taylor et al. 1999). In the Western Cape it is estimated that there about 4000 farm reservoirs storing in excess of 100 million cubic meters of water (Davies and Day 1998). In the winter rainfall region, the total water storage capacity of farm dams exceeds all permanent natural wetlands in the region (DWAF 1986, Davies and Day 1998)

Magnall (1999) stated that anthropogenic transformations in ecosystem processes have received little conservation attention and that this provides an obstacle to effective biodiversity conservation in South Africa. He added that there is a general lack of knowledge of the biological importance of artificial waterbodies and that this needs to be carried out in parallel to the conservation of natural wetland s in order to determine their roles as alternative refuges for biodiversity.

There are few studies dealing with the importance of farm dams for waterbird conservation (Davidson and Delany 2000), particularly in southern Africa (see Skead & Dean 1977, Guillet and Crowe 1986, Taylor et al. 1999). The only major study has been that of Froneman et al. (2001) who dealt with the importance of structural and habitat parameters of farm reservoirs in agricultural landscapes in defining and supporting different communities of waterbirds. Other waterbird studies that have been carried out at artificial waterbodies include Allan et al. (1996) who conducted baseline surveys during the construction of Mohale Dam in Lesotho and Swanepoel et al. (2006) who highlighted the poor conservation role of a large impoundment in the Western Cape.

In this paper I present an analysis of the data obtained from long-term waterbird monitoring at Droëvlei Dam, a farm dam in the Malmesbury district of the Western Cape. The focus of the paper looks at the comparison of monthly surveys with six monthly surveys and describes waterbird abundance and patterns of occurrence. Causes of population fluctuation are briefly assessed. The paper ends with a look at the importance of the dam for waterbirds in the region and a discussion of the role of farm dams in waterbird conservation in the WRR.

Study site

Droëvlei Dam (33°38'S, 18°43'E) is a private farm dam situated 20 km south of Malmesbury, South Africa. It is situated on the farm 'Droëvlei' (meaning *'dry wetland or marsh'*) close to the R304, a main road that links Malmesbury with the northern suburbs of Cape Town (Figure B.1, Plate 4.1). The Malmesbury district is an expansive agricultural area where intensive wheat cultivation takes place; large (> 50 ha) farms are scattered throughout the landscape. Some grape and olive farming occurs but at less intensive scales as the wheat farming. There are some broiler farms located close to Droëvlei Farm.

The farm lies within the winter rainfall region of South Africa; this region is described in detail by Harebottle et al. (2008) and in Chapter 1. Malmesbury, the nearest weather station records an average of 520 mm of rain annually of which 80% falls during the local winter months of April to September.

The dam has an earth wall; it ranges in area between 4–14 ha depending on water levels (Figure B.1). The dam receives inflow from a stream which arises in the Paardeberg mountain about 10 km to the west of the dam. Flow usually begins in late April or May and inflow continues until about October. Water is lost from the dam by evaporation, by spill-over and by use during the dry season for irrigation purposes. During drought periods the dam dries out totally in some years. In the dry season the dam separates into two distinct waterbodies; for example, in March 1988 the western portion covered 8 ha and the eastern portion 1.5 ha. The dam wall was raised in 1986 between February and April. A bulldozer was used and there was a high degree of human disturbance during this period. Additional alterations were noted during surveys in March 1987 and January 1988.

Fennel-leaved pondweed *Potamogeton pectinatus* is the dominant aquatic plant in the dam and surface emergent fronds may cover up to 90% of the dam surface towards the end of the dry season.

Methods

Surveys of waterbirds were carried out during two periods: monthly from November 1982 to May 1990 and six-monthly from July 1995 to February 2006; the former formed part of the Southern African Waterfowl Census (SAWC, see Chapter 1) The six-monthly surveys incorporated mid-summer and mid-winter surveys as part of the Coordinated Waterbird Counts (CWAC) programme of the Animal Demography Unit, University of Cape Town.

The surveys during for both periods were conducted primarily in the morning (between 0900 and 1100), and usually in the first two weeks of the survey month. For the CWAC surveys mid-winter surveys were carried out in July while summer surveys were conducted in either January or February. Observers varied during both survey periods and results of surveys were submitted using standardized census forms. Surveys from 1982 to 1990 initially comprised only surveys of anatids, grebes, Red-knobbed Coot, Great White Pelican, Greater Flamingo and Lesser Flamingo. From September 1985 the surveys included all waterbirds. The CWAC surveys included surveys of all waterbird species.

Species were divided into southern African residents and Palearctic migrants (see Chapter 1). Seasonality, abundance and trend analyses follows closely that of Appendix A. Overall waterbird abundance and diversity was assessed for the period September 1985–May 1990 when all waterbird species were surveyed. Trend analyses for the anatids, grebes, Red-knobbed Coot, Great White Pelican, Greater Flamingo and Lesser Flamingo were based on the surveys from November 1982 to May 1990; inter-annual variation for all other species were based on the period September 1985–May 1990.

Results

Overall abundance and species richness

SAWC surveys

A total of 91 monthly surveys was carried out between November 1982 and May 1990, and included 47 summer surveys and 44 winter surveys. Fifty species of waterbirds were surveyed. Fourteen species were counted on all 91 surveys, while an additional 36 species were counted on 57 surveys from September 1985, the latter incorporating 30 summer surveys and 27 winter surveys (Table B.1). For the latter, 20 species (40%) were recorded in 25% or less of all the surveys and in numbers that did not, on average, exceed 10 individuals (Table B.1).

Overall, numbers of waterbirds at Droëvlei Dam ranged between 201 (September 1989) and 3 577 (February 1989) from September 1985 to May 1990. Mean summer counts were two-fold higher (1 935 ± 973 birds) than mean winter counts (791.8 ± 476.4 birds). The mean number of waterbirds counted per month ranged between 319 in August and 2 646 in February.

Overall, the summer surveys were dominated by five species which made up 59% of all waterbirds at the site: namely Egyptian Goose (17%), Ruff (15%), White-winged Tern

(10%), Little Stint (9%) and Red-knobbed Coot (8%). The winter surveys were dominated by Red-knobbed Coot (24%), Egyptian Goose (9%), Cape Shoveler (8%), Yellow-billed Duck (8%) and Little Grebe (7%).

CWAC surveys

A total of 22 surveys was conducted which incorporated 11 mid-summer and 11 mid-winter surveys. Overall 47 species were recorded (Table B.1); 24 (51%) species were recorded in less than 25% of surveys and in numbers that did not exceed a mean of 10 individuals (Table B.1).

Mean summer counts (2 245 ± 1 847 birds) revealed a five-fold difference when compared with mean winter counts (437 ± 533 birds) although the variation displayed by the standard deviations remained similar. The highest and lowest summer counts were 3346 and 100 waterbirds in January 1999 and February 2006 respectively; in winter the highest and lowest counts were 684 and 206 counted in July 2000 and July 2005 respectively.

Egyptian Goose dominated the summer surveys, which, on average, comprised 64% of all waterbirds; Blacksmith Lapwing and Great White Pelican were the only other species that were numerical abundant contributing 6% each to the overall summer waterbird population. In winter, Red-knobbed Coot (11%), Kittlitz's Plover (10%), Cape Shoveler (10%), Red-billed Teal (9%), Yellow-billed Duck (8%) and Blacksmith Lapwing (6%) comprised more than half of the waterbirds at the dam.

Resident species

Overall, the number of resident waterbirds increased in early summer (October–December), peaked during late summer (January–March) and declined by over 50% during the winter months (Figure B.2, Table B.1); summer populations averaged 1123 ± 361 and the mean winter population was 567 ± 286.

Waterfowl dominated the resident avifauna and comprised 76% and 81% of the total resident species in summer and winter respectively. Within this group, Egyptian Goose comprised, on average, 29%, Red-knobbed Coot 14% and Yellow-billed Duck 9% of the summer population, while Red-knobbed Coot, Egyptian Goose and Cape Shoveler constituted 27%, 11% and 9% respectively to the winter population.

Shorebirds were the second most dominant group and comprised 16% and 11% of the summer and winter waterbird population respectively at the dam. Blacksmith Lapwing and Kittlitz's Plover were the most abundant shorebirds during summer and winter and comprised 10% and 5%, and 5% and 4% respectively of this group (Table B.1). Greater

Flamingo was the only wader that contributed significantly to the resident waterbird population, comprising 4% of the total winter population (Table B.1).

Waterfowl

Ducks and geese

For SAWC, Egyptian Goose showed a strong seasonal pattern of occurrence; numbers peaked in late summer (February–March, max. 902 in April 1990) with a sharp decline in May and fewer than six birds on average from June to September. Similarly, Spur-winged Goose showed a strong seasonal pattern; numbers increased during late summer (March–April) and peaked at the start of winter (max. 182 in April 1985) and then declined dramatically from May–November (Figure B.4) with numbers less than 5 birds during this seventh-month period. The CWAC surveys showed a four-fold increase in mean number of birds during summer, and a five-fold decrease during winter (Table B.1).

Yellow-billed Duck had marked dry season peaks. Numbers, on average, increased at the onset of summer, peaked from February to April with most birds occurring in March (max. 541 in March 1985) and then declined during winter; overall less than 50 birds were present at the dam from July–November (Figure B.4). Surveys during CWAC showed both summer and winter declines compared with SAWC; means of 8.5 birds during summer and 33.5 birds during winter represented 11-fold and two-fold changes compared with summer and winter surveys from SAWC (Table B.1).

Numbers of Cape Shoveler fluctuated on a monthly basis and showed no strong seasonal pattern. Maximum numbers generally occurred between October and March (max. 217 in October 1985); July and August were the only months that had counts below 50 birds (Figure B.4). CWAC showed mean counts of 7.9 and 43.3 during summer and winter respectively; the summer mean represented an almost eight-fold decrease in the number of birds since SAWC, and abundance patterns in winter were similar to those during SAWC (Table B.1).

Maccoa Duck showed erratic seasonal occurrence. On average, numbers tended to decline in late summer (February–March) and increased during winter into early summer (max. 115 in May 1990) (Figure B.4). Mean summer and winter surveys for CWAC showed a 10-fold and 7-fold decreases in numbers respectively (Table B.1).

A weak seasonal pattern was displayed by Southern Pochard; numbers peaked in mid-summer (max. 99 in December 1982) and declined sharply towards the end of summer (Figure B.4). Numbers remained low (< 5 birds) during winter but sporadic occurrences tended to occur during June and August. Southern Pochard numbers declined drastically during CWAC with mean summer surveys showing an almost 100% decline; no birds were recorded during winter compared with SAWC (Table B.1).

Cape Teal showed a clear dominance during the dry summer period and a decline during winter, although numbers did fluctuate during the summer. Numbers generally peaked from February–April (max. 189 in April 1990) with less than 20 birds between May–August (Figure B.4). On average, 50% fewer birds were present during the summer CWAC than the SAWC surveys; winter showed similar declines with up to 40% fewer teals during winter than the SAWC surveys (Table B.1). In terms of trends in abundance, the Cape Teal showed significant upward trends for summer ($r = 0.92$, $p < 0.01$) but not for winter (Figure B.7).

Red-billed Teal was regularly recorded in small numbers (mean 16 birds). Numbers peaked in mid-summer (maximum of 124 recorded in December 1998) and tended to decline during the winter (Figure B.4). CWAC revealed an almost 50% increase in the mean number of birds during summer, and mean winter surveys showed a four-fold increase (Table B.1). SAWC showed significant increases in numbers of this species during summer ($r = 0.71$, $p < 0.05$) and winter ($r = 0.71$, $p < 0.05$) (Figure B.7)

Red-knobbed Coot

Numbers of Red-knobbed Coot remained fairly constant throughout the year (mean 247 birds) and showed no clear seasonality; numbers tended to increase in early winter (max. 710 in May 1986), and decline in late winter (Figure B.4). They showed significant downward trends during summer ($r = –0.77$, $p < 0.01$) and winter ($r = –0.92$, $p < 0.01$) (Figure B.7). These declines were reflected during the CWAC surveys; mean summer surveys declined by up to 95% and the average winter surveys showed a five-fold decrease since the SAWC (Table B.1).

Grebes

Only the Black-necked and Little Grebes occurred in numbers large enough to make inferences about the occurrence at Droëvlei Dam. Black-necked Grebes showed greater abundance in summer (mean 20 birds) than in winter (mean 10.7 birds) during SAWC (Table B.1). Numbers generally peaked in December with decreasing number of birds from January–March. A maximum of 148 birds was recorded in November 1985. For CWAC, low numbers of birds were recorded with a mean summer count of 1.5 birds and a mean winter count of 2.5 birds, which represented declines of over 95% since SAWC. The summer maximum count of six birds is a 96% drop from the 148 birds recorded during SAWC;

winter shows similar trends (Table B.1). A similar pattern emerges for the Little Grebe. The species showed a strong late-summer seasonal peak during SAWC, although overall summer and winter means differ only marginally (Figure B.4). In terms of trends, larger numbers of birds, on average, were seen during SAWC than during CWAC during both summer and winter (Table B.1). There was a 97% reduction in numbers between the two survey periods.

Reasons for both species' declines at the dam could probably be explained by variations in food abundance caused by changes to the water quality and periods of inundation. Water-levels during summer at the dam during CWAC were low (M Delport pers. comm.) which resulted in shallow open-water which was not suited to these species diving feeding habits.

Reed Cormorant

Reed Cormorant occurrence showed strong seasonality from 1985–1990; numbers peaked during the dry season (January–March; max. 143 in February 1990) with few birds present during the wetter months (May–November) (Figure B.5). This pattern suggests considerable movement to and from Droëvlei Dam on an inter-annual basis. The CWAC surveys showed larger numbers, on average, during winter than during summer (Table B.1) with decreased abundances since the SAWC surveys.

Flamingos and other large wading birds

Greater Flamingo showed no strong seasonal pattern of occurrence at Droëvlei Dam. On average, numbers fluctuated throughout the year (mean 26 birds) with peaks between March and July (max. 214 in April 1987) (Figure B.6). Fewer than 20 birds were recorded between August and November. Numbers during CWAC showed similar seasonal abundances (Table B.1). In contrast, Lesser Flamingo abundance was strongly seasonal with early winter peaks between April and June (max. 315 in June 1986) (Figure B.5). Surveys conducted during CWAC revealed zero birds during summer and a winter mean of 13 birds. Lesser Flamingo showed significant population declines during SAWC for summer ($r = -0.73$, $p < 0.05$) and winter ($r = -0.70$, $p < 0.05$) (Figure B.5).

Other large wading birds were generally uncommon at the dam and occurred in small numbers. African Sacred Ibis occurred in small numbers during SAWC; the CWAC surveys showed an increase in the abundance of this species during both summer and winter (Table B.1); Glossy Ibis showed a similar pattern but only during summer. Cattle

Egret and African Spoonbill peaked in relatively large numbers during SAWC, but both occurred in smaller numbers during CWAC (Table B.1).

Gulls

The only gull to occur frequently was Kelp Gull; it was mostly recorded during CWAC surveys. The SAWC surveys showed few birds with a maximum of 11 birds recorded in July 1986. Overall, mean summer and winter counts both recorded < 2 birds. The mean summer and winter counts for CWAC were 15.1 and 16.6 respectively with a maximum of 107 birds recorded in February 2004.

Shorebirds

Blacksmith Lapwing and Kittlitz's Plover showed strong seasonality during SAWC; both species dominated during late summer (December–February) with peak numbers during January (Figure B.5, Table B.1). Maximum counts of 274 lapwings and 288 plovers were recorded during January 1987. CWAC surveys during summer suggested that mean abundance of Blacksmith Lapwings decreased. More Kittlitz's Plovers seem to be present in recent times (Table B.1).

Black-winged Stilt showed some seasonality (Figure B.5). On average 19.5 and 11.1 birds were recorded during summer and winter during SAWC; results from CWAC suggested that summer counts declined between the two periods (Table B.1). Maximum counts of 53 in April 1989 and 52 in January 1989 showed that peak occurrence can occur in summer or in early part of winter and within the same annual cycle.

Monthly occurrence of Pied Avocet during SAWC showed no strong seasonal preference although peaks tended to occur from December–March (Figure B.5). A maximum of 193 were recorded in April 1987; mean summer and winter counts were 26.5 and 10.4 birds respectively. Declines occurred during winter but with small resurgences. The CWAC surveys showed reduced mean summer counts (16 birds) but similar winter means (10.3) compared with the SWAC surveys. The maximum count occurred during summer (60 birds recorded in February 2003).

Breeding was recorded in three species during SAWC and occurred at low densities (three pairs or fewer; Table B.3); Blacksmith Lapwing bred in July, August and February, Black-winged Stilt in July, August and October, and Kittlitz's Plover in July, August and January.

Great White Pelican

This species was an irregular visitor to Droëvlei Dam during SAWC and showed summer peaks (Figure B.5). Although peak numbers of 52 and 51 birds were recorded in March 1990 and December 1985, fewer than six birds were recorded on average during summer or winter (Table B.1). Pelicans were largely absent between April and November. CWAC showed larger summer means (126.8 birds) than winter means (12.5 birds). The peak count of 400 birds was recorded in February 2003.

Palearctic migrants

During SAWC, 10 Palearctic migrant species occurred at Droëvlei Dam (Table 1). Birds arrived in September, peaked during January and February and departed in April; few birds remained during the austral winter (Figure B.3c). Ruff, Little Stint and Curlew Sandpiper together constituted 73% of Palearctic migrants, and White-winged Tern 26%.

Little Stint numbers peaked from December–February (max. 920 in February 1989), Ruff peaked from January–March (max. 837 birds in February 1989) and Curlew Sandpiper numbers peaked in October (max. 365 birds in October 1987) (Figure B.5). The latter did exhibit more variation during the summer months. White-winged Terns increased in November, peaked in mid-summer (max. 590 birds counted in February 1990) and then departed by the end of April (Figure B.5). Overall, mean summer counts for CWAC showed lower abundances for Ruff, Little Stint, Curlew Sandpiper and White-winged Tern, although the largest flock for White-winged Tern (700 birds in January 2000) was recorded during this period (Table B.1)

The conservation importance of Droëvlei Dam for waterbirds

Droëvlei Dam supported a number of waterbird species that are important relative to respective population thresholds (Table B.4). During SAWC surveys, Maccoa Duck and Pied Avocet surpassed 1% of their estimated global populations on at least one occasion (Table B.4, Wetlands International 2006). Six species reached southern African IBA thresholds (Barnes 1998): Black-necked Grebe, Maccoa Duck, Cape Shoveler, Yellow-billed Duck, Lesser Flamingo and Pied Avocet reached levels that represented more than 0.5% of their estimated southern African populations. When considering the CWAC data, only the Great White Pelican surpassed the 1% threshold level. Neither Maccoa Duck nor Pied Avocet, which reached 1% levels during SAWC, reached these levels during CWAC. Egyptian Goose, Great White Pelican and Cape Shoveler were the only three species that reached or surpassed sub-regional IBA levels; the Cape Shoveler was the only species that reached 0.5% levels during both survey periods.

The SAWC surveys had three species whose maximum counts contributed to more than 10% of the estimated Western Cape population: White-winged Tern (17%), Maccoa Duck (14%) and Ruff (14%) (Table B.4). The CWAC surveys showed some changes to this: White-winged Tern remained top and showed a slight increase, to 20%, but Great White Pelican increased from 2% to 15% and Egyptian Goose from 3% to10%; Ruff declined to 6% and Maccoa Duck to 3%. Pied Avocet, Yellow-billed Duck, Spur-winged Goose and Little Stint also showed decreases (Table B.4). CWAC surveys could have missed peak occurrences during non-surveyed months and therefore occurrence at the site could be under-estimated. Consequently, these comparisons should be interpreted cautiously.

Three Red Data species were recorded at Droëvlei Dam: Lesser Flamingo (Near-threatened), Greater Flamingo (Near-threatened) and Great White Pelican (Near-threatened) (Barnes 2000). The Lesser Flamingo was the only species to occur at regionally significant levels but this occurred only once (Table B.4). Both flamingo species showed declines towards the end of the 1980s; the Lesser Flamingo was not recorded after the winter of 1987 and Greater Flamingo was recorded in low numbers. The CWAC surveys recorded both species but at lower overall mean numbers during summer and winter than during the SAWC surveys, suggesting that the flamingos have returned to the dam.

Although Palearctic shorebirds did not occur in any globally significant numbers during SAWC or CWAC, their occurrence at Droëvlei Dam does suggest that it provides suitable alternate habitat during the austral summer. Curlew Sandpipers tend to use the site early on in the season (October, Figure B.5) and numbers of Little Stint and Ruff peaked towards the end of summer suggesting that they use the dam prior to their autumn migration. During this period the dam was at its lowest water levels which probably accounts for their occurrence at these times.

Waterbird Conservation Value (WCV) score

The monthly waterbird conservation value scores (WCV) scores for Droëvlei Dam between November 1982–May1990 (SAWC surveys) are shown in Figure B.8. The WCV scores after September 1985 incorporated all waterbirds while those prior to this date included only the 19 focal species surveyed by SAWC. The September 1985–May1990 data should be seen as the standard, overall WCV scores; the pre-1985 data are included mainly for comparative purposes for the species concerned.

Overall, scores were relatively small with most values below 3.0 (compare with Chapters 2 and 3). Seven surveys had values of 2.0 or more, and January 1987 revealed the largest index (2.97). Although inter-annual fluctuations were evident, generally summer scores were higher reflecting larger populations of waterbirds during this time. This is supported by the seasonal abundance data presented in this paper. There was a drop-off in numbers into winter, and usually August and September had the lowest scores.

For the six species that reached 1% or 0.5% threshold levels (see above, Table B.4), their annual occurrence patterns are shown colour coded in Figure B.8. It is noticeable the amount of monthly and inter-annual variation between the species. Maccoa Duck, for example, contributes fairly regularly to the scores from January 1985 and then is absent from January 1989–July 1989 with a strong resurgence from October 1989. Prior to September 1985, a similar pattern seems to be evident (Figure B.8). Pied Avocet is erratic in its occurrence and has two periods (January 1987 and January 1989) during which it occurs in large numbers. Black-necked Grebe also occurred erratically and seemed to have been more abundant early on in the surveys (i.e. September–December 1985) than during later surveys. Yellow-billed Duck and Cape Shoveler occurred almost throughout the study period with periods of abundance and then periods of scarcity. At times, the two species abundance mirrored each other (e.g. February–May1986, January–May 1998) but also times when one species was more abundant than the other (e.g. February–March 1985, September–November 1985, April–June 1987 and March–April 1990). Lesser Flamingo also occurred irregularly but when it did it did make large contributions to the WCV score at the dam (e.g. May–June 1983, March 1984 and June 1986).

On some occasions (January–February 1986, January 1987, January 1989 and March–April 1990) the WCV score for 'Other' species was larger (often exceeding the 1% level) than for either or combination of the conservation important species. The proportion they contributed to the overall index was substantial and highlighted the cumulative value of species that are deemed not to be conservation worthy species. This then emphasized the overall value of the WCV score as an important conservation tool that encompasses not only species that occur proportionately in high abundance, but also species that occur in relatively small numbers, but cumulatively are valuable (see Chapter 2).

Figure B.9 shows the relationship between the monthly WCV score and the total monthly counts from September 1985–May 1990. Although the relationship is relatively strong, that as abundance increases so the WCV score increases, there are times when large numbers of birds (> 2 500 birds) result in low WCV scores There are also times when abundance is low (*c.* 1 000–1 700 birds) but the WCV score is high which translates to more species having a proportionately higher number of birds in relation to their 1% threshold levels and hence having a larger WCV score. It can be argued that it is at these times that the site has a higher waterbird conservation value than when the site supports a greater abundance of birds.

Discussion

Seasonal variation of waterfowl

Patterns of waterfowl occurrence and abundance at Droëvlei Dam varied but seven of the 11 species (Egyptian Goose, Spur-winged Goose, Yellow-billed Duck, Cape Teal, Red-billed Teal, Southern Pochard and South African Shelduck) showed summer peaks, indicating the importance of the dam as a dry-season refuge. Cape Shoveler and Maccoa Duck were the only species to show no clear seasonal pattern and with larger winter numbers than any other of the Anatidae (Figure B.4).

Three species of ducks were recorded moulting at the dam during SAWC (Table B.2). Cape Shoveler and Cape Teal start to moult in October with larger numbers of shovelers (max. 32 birds in Oct. 1985) compared with the teals. The moulting period for the Cape Shoveler ended in December whereas some Cape Teals moulted through to January. Peak number of moulting birds for Cape Teal occurred in December (max. 11 birds in Dec. 1989). Numbers of moulting Egyptian Geese peaked in December (max. 10 birds in Dec. 1989) and this was also the month in which moulting started in this species (Table B.2); most Egyptian Geese finished their moult in February. Based on the seasonal abundance for these species (Table B.1), it is clear that only a small percentage of these three species actually moult at the site, but it nevertheless indicated the safe refuge the dam provided for moulting waterfowl. No moulting data was provided for CWAC so no trend comparisons could be drawn between the two survey periods.

Ten species of waterfowl used Droëvlei Dam for breeding with most breeding activity taking place from September to January (Table B.3). The ducks and geese bred mainly from September to December and the three grebe species (Little, Black-necked and Great Crested) bred from December to April. Red-knobbed Coot was the only species recorded breeding during winter; the grebes, ducks and geese were largely absent during the winter months. Paarl Waste Water Treatment Works showed winter influx of Little Grebe (Harebottle 2008, Appendix A) and it is probable that at least a proportion of the population may come from Droëvlei Dam following breeding as the site is less than 30 km away. The decline in numbers of most waterfowl in early winter coincided with the onset of winter rain (Figure B.8) and suggests that as temporary water bodies fill in the surrounding landscape most birds move to these areas to breed (Little 1995, Harebottle 2008). This relationship was strongest for Yellow-billed Duck, Egyptian Goose and Cape Teal.

How important is Droëvlei Dam for waterbirds?

The largest single count of waterbirds at Droëvlei Dam was 3 576 birds which in the context of farm dams is relatively high (Table B.1). It is representative of a large number of farm dams, large and small, scattered across the agricultural regions of the winter rainfall region. Cumulatively, these dams account for a large number of waterbirds. It is therefore of interest to consider the service functions for waterbirds which can be performed by farm dams such as Droëvlei Dam. This wetland, and others like it, variably fulfilled four important requirements for several species of waterbirds: safety from predators and disturbance, food, breeding habitat and moulting refuge.

Many of the waterbirds that used Droëvlei Dam made little or no use of food in the wetland. The pelicans and Kelp Gulls primarily used the dam for roosting as they foraged away from the dam at nearby municipal refuse dumps. For the geese, and many ducks, it was a safe day-time refuge between nocturnal forays to forage at alternative sites and habitats. It was safe because the most threatening predators and causes of disturbance are terrestrial animals, including humans, which are deterred by water and especially deep water. Given the effective safety the dam offers, waterbirds can roost, forage for food if this is available, breed if there is suitable nesting habitat, or undertake their annual moult during which they may become less efficient fliers or, in the case of waterfowl, may become totally flightless.

Waterbirds are adapted to dynamic natural habitats that may change radically on an intra- as well as inter-annual basis for example the flooding and drying out of shallow seasonal wetlands, or the changes in floodplain conditions of major rivers. Accordingly most waterbirds must regularly carry out reconnaissance of the state of regional wetlands to establish where conditions are suitable for safety and feeding. In the course of these reconnaissances they may stop over at different wetlands for short periods. Such reconnaissance visits are the likely cause of the intra-seasonal fluctuations in the numbers of waterbird species at Droëvlei Dam and of the irregular occurrences of some of the less numerous waterbird species. For example, nomadic specie such Pied Avocets and Black-winged Stilts (Tree 1997a, b) showed winter resurgences at Droëvlei which suggested that these species move unpredictably between wetlands.

Seasonal changes occur in the physical state of the dam and in the needs of particular species or groups of species that use this wetland. In the case of the birds these need consideration at local, regional and global levels. On the global level Palearctic shorebirds, which breed in northern Eurasia, pass their contra-nuptial period in warmer climates to avoid the severe boreal winter. Nine of these shorebird species, and the White-winged Tern which breeds on seasonal wetlands in south-central Eurasia (Tomiałojć and van der Winden 1997), have been recorded at Droëvlei; their occurrence at the dam is primarily or solely during the austral summer. The terns feed largely on aquatic insects whose numbers are highest in this season and the more numerous of the shorebirds forage in the shallow waters or exposed waterlogged soils of the dam as the water level draws down through the mid to late summer.

Several of the resident southern African species are also (mainly) non-breeding visitors to the winter rainfall region. These include the two flamingos and the African Pochard (Hockey et al. 1989). All three species breed in the summer rainfall regions of southern Africa and when seasonal wetlands in the summer rainfall region dry out they move to wetlands either at the coast, in the case of flamingos, or, in the case of all three species, to wetlands in the winter rainfall region.

Regionally resident waterbirds have differing reasons for seasonal changes in their use of Droëvlei Dam some of which are readily understandable, others which are not. The two species of goose leave the wetland at the start of the winter rains. Presumably they then disperse to graze on newly sprouting grasses. They do not return to the dam until the regional spring, after they have bred, and at least some moult at the dam. The ten species of regionally resident ducks that occur at Droëvlei Dam have similar seasonal needs. After seasonal rains have raised ground water levels to the extent that low lying areas flood, most of these ducks disperse to forage and breed at these seasonal shallow wetlands. Such wetlands, because they normally dry out annually, have no fish and without competition from fish there is a higher density of aquatic invertebrates and seeds for the ducks to feed on. Also because these wetlands are shallow they are suitable for ducklings, which in these precocial species must feed themselves and to do so need to be able to dabble down or dive to the benthos where food is most concentrated. As the shallow wetlands dry out through the early summer these ducks move to more permanent waterbodies such as Droëvlei Dam where the adult birds undergo their annual flightless moult. For the Reed Cormorant its late summer peak at Droëvlei suggests a post-breeding influx; the dam does not provide suitable breeding conditions for colonial nesting birds (M Delport pers.comm.). Reed Cormorants breed from July–January in the south-western Cape (Hockey et al. 1989) and dispersion to non-breeding sites probably takes place soon after the end of the breeding season.

Regional population changes

Several waterbird species have undergone appreciable changes in their status at Droëvlei Dam over the 18-year study period, some experiencing substantial decrease in numbers others a marked increase. None of these changes can be attributed to any change at the wetland.

The regional population of Kelp Gulls has increased over the past decades, probably because the provision of food at municipal waste dumps enables more young birds to survive (Steele and Hockey 1990) and because this species is no longer confined to offshore islands but now breeds at several mainland localities. There has been a concomitant increase in the occurrence of this gull at inland localities (Swanepoel et al. 2006). The population of the Great White Pelican has also increased in part through better protection of the single regional breeding colony at Dassen Island (Williams and Borello 1997), but also because this species has taken to foraging on waste at pig and poultry farms as well as at municipal dumps (Crawford et al. 1995, de Ponte Machado 2010). Presumably both species have been increasingly attracted to the region around Droëvlei Dam by the availability of waste products and use the dam as a resting place. The increase in numbers at Droëvlei Dam between SAWC and CWAC was consistent with the regional population trend.

The regional populations of both species of goose have been increasing over the past decades in part due to a decrease in hunting pressure (Magnall 1999, Magnall and Crowe 2001). Most of the species that have decreased markedly across the 23 years are migrants and, in the absence of any obvious regional reasons for their decrease, it is assumed that they are affected by factors either in their breeding regions or en route between breeding and contra-nuptial areas.

The role of farm dams in waterbird conservation

The primary purpose of farm dams is water storage for crop irrigation and/or as drinking provision for stock. These dams are usually earthen and deep maximizing storage capacity while minimizing construction and maintenance costs. Deep dams provide good habitat for waterfowl and other open-water species (e.g. grebes and coot). Larger dams seem to be exploited more often by waterbirds providing more space and resource partitioning allowing larger numbers and greater species richness (Davidson and Delany 2000, Froneman et al. 2001). They also provide ideal refuges as moulting sites and with few natural deep wetlands in the Western Cape (see Davies and Day 1998), most waterfowl in the Western Cape use artificial sites as summer or moulting refuges (Siegfried 1967, Kaletja-Summers et al. 2001a,b; Harebottle et al. 2008). This highlights the importance of artificial sites in providing suitable habitat and conditions for waterfowl.

Historically, at least before the first large state dams were built in South Africa (*c.* 1930s, Davies and Day 1998), waterfowl and other waterbird populations in the WRR would have had to move significant distances after breeding to find suitable large waterbodies at which to moult. These migrations would have been annual and some probably involved long-distance movements to summer rainfall regions (Davidson and Delany 2000). As an increased number of impoundments and farm dams were constructed in the WRR the need to move to distant moult sites became retracted and shorter moult migrations were undertaken. Although current migration patterns are still poorly understood for many waterfowl species (Underhill et al. 1999), it is probable, through the provision of these artificial wetlands, that some species have altered their migratory patterns and routes in the last five to six decades. Davidson and Delany (2000) suggested that the creation of year-round habitat can lead to changed seasonal pattern of movements, particularly for open-water species (incl. grebes, ducks and geese). In some cases they may now remain at their breeding sites to moult (e.g. Strandfontein Sewage Works; Kaletja-Summers 2001b).

While there are thousands of farm dams scattered around the WRR, and many the size of Droëvlei Dam, the use of and inter-connectivity between these farms dams by waterbirds is poorly understood. They have undoubtedly provided suitable alternative habitats to the larger, historically well-known and well-used wetland sites in the region and may afford certain species better feeding, breeding or moulting opportunities. For example, Radyn Dam (33°18'S, 18°45'E) a 3.5-ha farm dam 20 km north of Malmesbury supports up to 1 750 South African Shelduck regularly during summer (CWAC unpubl. data). Many farm dams have vegetated islands and these have become common breeding sites for colonial breeders such as herons, egrets and ibises (B de Kock pers. comm., F Ellmore pers. comm.).

Connectivity between farm dams and other larger permanent wetlands does occur (e.g. regular movement of Egyptian Goose flocks flying between Rietvlei Wetland Reserve and Droëvlei Dam; DMH pers obs; AJ Williams pers. comm.), but as at farm dams, this connectivity is not well understood (Haig et al. 1988). Waterbirds are largely opportunistic in their behaviour and will utilize any suitable habitat they find and consequently move around in response to environmental conditions (Little et al. 1995, Davidson and Delany 2000). Some species (e.g. South African Shelduck, Cape Shoveler), however, have preferred moult or post-breeding refuge sites and these are used regularly (Siegfried 1967). This seasonal use of different sites highlights the importance of these sites in the species' annual cycle and the need to establish conservation measures at a regional level. Since Droëvlei Dam supports large numbers of Egyptian Goose, many of which moult there, more intensive population monitoring (including colour-banding) could be encouraged in order to track changes in abundance, movements and survival.

Management actions and recommendations

Ideally Droëvlei Dam, and other similar farm dams, should be managed in ways to offer viable habitat for waterfowl populations, particularly for Egyptian Goose; this species, and other Anatidae, primarily use the dam for moulting and as a non-breeding refuge. Although numbers of Egyptian Goose are on the increase in the Western Cape and regarded as a pest species by farmers (Magnall and Crowe 2001), the species should be afforded some protection. It is a huntable species in the Western Cape (K.A. Shaw pers. comm.) and should population numbers exceed carrying capacity (i.e. it reaches pest status), sustainable and regulated hunting could be carried out in order to control numbers. In 2011, the daily bag limit per licensed hunter was 10 for Egyptian Geese (Province of the Western Cape 2010).

As a privately owned dam and site which supports important numbers of waterfowl species (Table B.1) the long-term protection of Droëvlei Dam needs to be considered. Froneman et al. (2001) suggested that proper management and landowner cooperation is important to secure farm ponds as viable waterbird habitat and conservation in the long-term. The 'Stewardship programme' administered by CapeNature (van Niekerk 2004, CapeNature 2009) which empowers landowners to commit to conservation practices on their property may be one solution in ensuring the long-term sustainability of the site. Similar initiatives have been implemented in The Netherlands (Van Paasen 1991) and Australia (Barrett 2000) where integrated approaches have been used to encourage bird conservation on farmlands.

Further research and monitoring is imperative to better understand the inter-connectivity and use of farm dams by waterbirds. Ongoing waterbird surveys at Droëvlei Dam and at other surrounding farm dams would add value to CWAC particularly in a more regional context. Increased ringing studies to mark individuals particularly of waterfowl species should be conducted in order to ascertain immigration and emigration from Droëvlei Dam and to gauge use of the landscape on an annual basis.

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Table B.1 Summary of waterbird surveys for Droëvlei Dam from 1982–1990 (Southern African Waterfowl Census = SAWC) and 1995–2006 (Coordinated Waterbird Counts = CWAC). Species marked with an asterisk were recorded on fewer than 25% of surveys during SAWC or CWAC respectively.

Species	SAWC (1982–1990)				CWAC (1995–2006)			
	Summer		Winter		Summer		Winter	
	Mean (± S.D.)	Min-Max[1]	Mean (± S.D.)	Min-Max	Mean (± S.D.)	Min-Max	Mean (± S.D.)	Min-Max
Residents								
Waterfowl								
Egyptian Goose	282 ± 199.3	2–882	72.3 ± 146	0–902	1453 ± 836.8	3–2600	14.5 ± 12.1	3–48
Red-knobbed Coot	236.5 ± 14	16–540	257 ± 39	3–710	9.3 ± 14.6	0–38	47 ± 36.9	5–115
Yellow-billed Duck	100.9 ± 73.4	6–541	56.5 ± 59.7	1–323	4.1 ± 5.9	0–15	33.6 ± 43.6	3–156
Cape Shoveler	74.5 ± 16.7	19–217	53.4 ± 12.5	6–167	8 ± 11.9	0–41	43.3 ± 58.7	0–200
Little Grebe	45.4 ± 29.2	0–151	40.9 ± 30.8	0–155	1.8 ± 2	0–4	11.3 ± 14.8	0–48
Cape Teal	42.9 ± 9.7	0–128	20.7 ± 13.6	0–189	18 ± 26.1	0–77	13.1 ± 14	1–45
Maccoa Duck	32.3 ± 11.3	0–111	32.3 ± 6.2	0–115	4.5 ± 5.6	0–14	5 ± 8.8	0–26
Red-billed Teal	20.6 ± 9.4	0–124	10.5 ± 2.9	0–58	37.6 ± 49.4	0–110	38.8 ± 40.2	2–114
Black-necked Grebe	20.1 ± 17.3	0–148	10.8 ± 6.6	0–77	1.5 ± 2.3	0–6	2.5 ± 3.7	0–9
Southern Pochard*	13.3 ± 12	0–99	4.7 ± 4.8	0–69	0.4 ± 0.9	0–2	–	–
South African Shelduck*	8.2 ± 6.7	0–60	1.5 ± 2.4	0–27	1.4 ± 2.3	0–6	0.8 ± 1.4	0–4
Spur-winged Goose*	6.1 ± 7	0–92	5.4 ± 11.4	0–182	15.3 ± 21.6	0–56	5 ± 5	1–18
Great Crested Grebe*	5.6 ± 1.6	0–21	2.2 ± 1.4	0–9	0.9 ± 1.2	0–3	0.7 ± 1.3	0–4
Hottentot Teal*	–	–	0.1 ± 0.1	0–1	–	–	–	–
Sub–total:	**887.8 ± 263.9**	**332–1768**	**567.8 ± 243.8**	**164–1675**	**1555.2 ± 979.7**	**3–2972**	**215 ± 239.9**	**15–787**
Pelicans				–				
Great White Pelican	**5.6 ± 4.7**	**0–52**	**1.3 ± 1.4**	**0–16**	**130.1 ± 142.5**	**0–400**	**12.5 ± 27.1**	**0–93**
Flamingos				–				
Greater Flamingo	24.1 ± 7.6	0–146	27.1 ± 11	0–214	16.7 ± 31.6	0–100	22.9 ± 30.8	0–109
Lesser Flamingo*	10.9 ± 13	0–242	45.4 ± 37.8	0–315	–	–	13 ± 39	0–130
Sub–total:	**35 ± 20.6**	**0–148**	**72.4 ± 48.7**	**0–440**	**16.7 ± 31.6**	**0–100**	**35.8 ± 69.8**	**0–239**
Cormorants and darter								
Reed Cormorant	23.7 ± 21	0–143	3.4 ± 4.4	0–26	4 ± 7.1	0–24	9.9 ± 17.5	0–61

Table B.1 contd.

Species	SAWC (1982–1990)				CWAC (1995–2006)			
	Summer		Winter		Summer		Winter	
	Mean (± S.D.)	Min–Max	Mean (± S.D.)	Min–Max	Mean (± S.D.)	Min–Max	Mean (± S.D.)	Min–Max
White-breasted Cormorant*	3 ± 2.8	0–18	2.1 ± 1.7	0–13	2.5 ± 2.3	0–6	6.2 ± 10.3	0–28
African Darter*	0.2 ± 0.2	0–2	0.1 ± 0.2	0–1	1 ± 1.5	0–4	2.1 ± 2.6	0–7
Sub–total:	**26.8 ± 23.9**	**0–156**	**5.6 ± 6.2**	**0–27**	**7.4 ± 10.8**	**0–34**	**18.1 ± 30.3**	**0–96**
Shorebirds								
Blacksmith Lapwing	107.1 ± 67.7	1–274	25.3 ± 30.2	4–209	131.1 ± 78.3	2–229	25.5 ± 11.8	5–41
Kittlitz's Plover	54.7 ± 55.8	0–288	21.1 ± 13.1	0–145	101.2 ± 89	0–339	44.5 ± 41.9	2–134
Pied Avocet	26.6 ± 17.4	0–193	10.4 ± 9.9	0–88	16 ± 22.9	0–60	10.3 ± 13.4	0–45
Black-winged Stilt*	19.5 ± 7.7	0–52	11.2 ± 10.4	0–53	13.4 ± 17.2	0–45	13.8 ± 15.6	2–57
Three-banded Plover*	0.7 ± 0.5	0–4	6.3 ± 5.7	0–35	2.6 ± 3.1	0–8	15.2 ± 17.1	5–65
African Snipe*	0.2 ± 0.4	0–4	–	–	0.7 ± 2.2	0–7	0.7 ± 1.6	0–5
Sub–total:	**208.6 ± 149.3**	**3–708**	**74.1 ± 69.2**	**5–378**	**264.8 ± 212.4**	**2–688**	**109.8 ± 101.1**	**14–347**
Gulls								
Kelp Gull*	0.3 ± 0.6	0–6	1.3 ± 1.4	0–11	14.3 ± 31.5	0–107	16.7 ± 22.8	0–82
Hartlaub's Gull*	0.2 ± 0.2	0–1	0.2 ± 0.4	0–3	–	–	–	–
Grey-headed Gull*	0.1 ± 0.2	0–2	0.1 ± 0.2	0–2	–	–	–	–
Sub–total:	**0.5 ± 0.9**	**0–6**	**1.6 ± 1.8**	**0–11**	**14.3 ± 31.5**	**0–107**	**16.7 ± 22.8**	**0–82**
Waders								
African Spoonbill	4.1 ± 4.5	0–41	0.9 ± 1.1	0–7	2.6 ± 3	0–7	0.7 ± 0.7	0–2
African Sacred Ibis	1.3 ± 0.5	0–6	0.6 ± 0.5	0–4	8 ± 6.1	0–18	20.6 ± 24	3–81
Grey Heron	1.3 ± 0.4	0–4	1 ± 0.4	0–3	2.2 ± 1.8	0–5	1.2 ± 1	0–3
Cattle Egret*	2.8 ± 4.2	0–26	0.1 ± 0.1	0–1	0.9 ± 1.3	0–3	2.8 ± 4.7	0–16
Yellow–billed Egret*	0.7 ± 0.6	0–6	0.1 ± 0.1	0–1	–	–	0.2 ± 0.5	0–1
Little Egret*	0.5 ± 0.9	0–11	–	–	1 ± 1.7	0–4	–	–
Glossy Ibis*	0.3 ± 0.4	0–4	0 ± 0	0–16	3.9 ± 12.7	0–42	–	–
Black-headed Heron*	0.2 ± 0.4	0–3	0.1 ± 0.1	0–1	0.7 ± 0.9	0–2	0.9 ± 1	0–3
Black–crowned Night–heron*	0.1 ± 0.2	0–2	0.1 ± 0.2	0–1	–	–	0.1 ± 0.4	0–1
Hamerkop*	0.1 ± 0.2	0–1	0.1 ± 0.1	0–1	0.2 ± 0.7	0–2	0.3 ± 1	0–3
Great White Egret*	0.1 ± 0.1	0–1	–	–	0.3 ± 1	0–3	–	–
Hadeda Ibis*								
Sub–total:	**11.2 ± 12.1**	**0–46**	**2.6 ± 2.4**	**0–9**	**19.3 ± 28.7**	**0–86**	**26.5 ± 32.9**	**3–110**

Table B.1 contd

Species	SAWC (1982–1990)				CWAC (1995–2006)			
	Summer		Winter		Summer		Winter	
	Mean (± S.D.)	Min–Max	Mean (± S.D.)	Min–Max	Mean (± S.D.)	Min–Max	Mean (± S.D.)	Min–Max
Palearctic migrants								
Shorebirds								
Ruff	292.6 ± 214.5	0–920	11 ± 24.3	0–139	108.6 ± 138.2	0–400	–	–
Little Stint	174 ± 100	0–837	16.9 ± 36.6	0–218	36.8 ± 35	0–91	0.6 ± 1.6	0–5
Curlew Sandpiper	86.3 ± 47.5	0–365	13.3 ± 11.4	0–112	17.2 ± 15.6	0–46	2.9 ± 8.1	0–27
Common Ringed Plover*	5.5 ± 2.9	0–18	0.6 ± 1.4	0–8	7.5 ± 7.4	0–25	0 ± 0	0–0
Common Sandpiper*	2 ± 4.9	0–59	0 ± 0	0–0	0.8 ± 1.6	0–5	–	–
Common Greenshank*	1 ± 1.1	0–5	0.2 ± 0.4	0–3	0.4 ± 0.7	0–2	0.1 ± 0.4	0–1
Wood Sandpiper*	0.2 ± 0.3	0–3	–	–				
Grey Plover*	0.1 ± 0.1	0–1	–	–				
Marsh Sandpiper*					0.6 ± 1.3	0–4	–	–
Sub–total:	**561.5 ± 370.9**	**0–1871**	**41.8 ± 73.9**	**0–370**	**171.6 ± 199.6**	**0–573**	**3.5 ± 9.9**	**0–33**
Terns								
White-winged Tern	**198.4 ± 127.6**	**0–590**	**25.1 ± 34**	**0–227**	**66.4 ± 210.3**	**0–700**	**–**	**–**
Sub total: Residents	**1175.2 ± 475**	**542–2827**	**725.2 ± 373.2**	**190–2465**	**2007.6 ± 1436.8**	**5–4387**	**434 ± 523.6**	**32–1754**
Sub–total: Palearctic migrants	**759.9 ± 498.4**	**3–3789**	**66.8 ± 107.8**	**0–740**	**238 ± 409.9**	**0–1273**	**3.5 ± 9.9**	**0–33**
Total waterbirds	**1935 ± 973.4**	**332–5701**	**791.9 ± 481**	**227–3002**	**2245.5 ± 1846.6**	**5–5660**	**437.5 ± 533.4**	**32–1787**

[1] The sub-total values here reflect the minimum/ maximum number for the group profile as a whole and not the sum of individual minima/maxima for each species which would represent estimated min./max. carrying capaicty and not actual min./max. numbers reflected by the dataset

Table B.2 Total monthly numbers of moulting birds of three waterfowl species at Droëvlei Dam from 1982–1990.

Species	Month												Total
	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar	Apr.	May	Jun.	Jul.	Aug.	
Cape Shoveler	–	32	5	1	0	0	–	–	–	–	–	–	38
Cape Teal	–	4	1	11	2	0	–	–	–	–	–	–	18
Egyptian Goose	–	0	0	10	9	3	–	–	–	–	–	–	22
Total	**–**	**36**	**6**	**22**	**11**	**3**	**–**	**–**	**–**	**–**	**–**	**–**	**78**

Table B.3 Monthly maximum numbers of breeding pairs of 13 resident waterbird species at Droëvlei Dam from 1982–1990.

Species	Month												Total
	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	
Cape Shoveler	2	5	2	1	–	–	–	–	–	–	–	–	10
Yellow-billed Duck	1	2	2	2	–	–	–	–	–	–	–	–	7
Cape Teal	1	2	1	1	–	–	1	–	–	–	–	–	6
Red-billed Teal	1	3	1	–	–	–	–	–	–	–	–	–	5
Egyptian Goose	–	1	1	3	2	1	1	–	–	–	–	–	9
Spur-winged Goose	–	–	1	2	–	–	–	–	–	–	–	–	3
Little Grebe	–	–	–	–	10	–	–	–	–	–	–	–	10
Black-necked Grebe	–	–	–	29	–	–	–	–	–	–	–	–	29
Great Crested Grebe	–	–	–	4	7	–	2	–	–	–	–	–	13
Red-knobbed Coot	13	15	12	4	1	3	1	–	4	–	14	7	74
Sub-total waterfowl	**18**	**28**	**20**	**46**	**20**	**4**	**5**	**–**	**4**	**–**	**14**	**7**	**166**
Blacksmith Lapwing	–	–	–	–	–	3	–	–	–	–	3	3	9
Black-winged Stilt	–	1	–	–	–	–	–	–	–	–	1	1	3
Kittlitz's Plover	–	–	–	2	1	–	–	–	–	–	4	2	9
Sub-total shorebirds	**–**	**1**	**–**	**2**	**1**	**3**	**–**	**–**	**–**	**–**	**8**	**6**	**21**
Total	**18**	**29**	**20**	**48**	**21**	**7**	**5**	**–**	**4**	**–**	**22**	**13**	**187**

Table B.4 Species of conservation importance at Droëvlei Dam. Global, regional and provincial population thresholds are shown for SAWC and CWAC and based on maximum counts for each species from 113 surveys from May 1982–April 2006. Species are sorted in descending order of global, regional and provincial importance. Species names are taken from Hockey et al. (2005). Species in bold are included in the South African Red Data book (Barnes 2000).

Species	Max. count		Threshold level					
			Global[1]		IBA[2]		Western Cape[3]	
	SAWC	CWAC	SAWC	CWAC	SAWC	CWAC	SAWC	CWAC
Maccoa Duck	115	26	1.2% (2)	–	18	–	14%	3%
Pied Avocet	193	60	1.0% (1)	–	3	–	4%	1%
Great White Pelican (NT)	52	400	–	2.0% (1)	–	6	2%	15%
Egyptian Goose	902	2600	–	–	–	5	3%	10%
Cape Shoveler	217	200	–	–	2	1	3%	3%
Black-necked Grebe	148	9	–	–	2	–	5%	–
Lesser Flamingo (NT)	315	130	–	–	1	–	5%	2%
Yellow-billed Duck	541	156	–	–	1	–	4%	1%
White-winged Tern	590	700	–	–	–	–	17%	20%
Ruff	920	400	–	–	–	–	14%	6%
Blacksmith Lapwing	274	229	–	–	–	–	8%	7%
Southern Pochard	99	2	–	–	–	–	6%	–
Little Stint	837	91	–	–	–	–	6%	1%
Kittlitz's Plover	288	339	–	–	–	–	5%	6%
Spur-winged Goose	182	56	–	–	–	–	4%	1%
Cape Teal	189	77	–	–	–	–	4%	2%
Red-billed Teal	124	114	–	–	–	–	3%	3%
Little Grebe	155	48	–	–	–	–	3%	1%
Reed Cormorant	143	61	–	–	–	–	2%	1%
Greater Flamingo (NT)	214	109	–	–	–	–	1%	1%
Black-winged Stilt	53	57	–	–	–	–	1%	1%
Red-knobbed Coot	710	115	–	–	–	–	1%	–
Curlew Sandpiper	365	46	–	–	–	–	1%	–
South African Shelduck	60	6	–	–	–	–	1%	–

[1] Calculated from Wetlands International (2006). Figures represent the percentage of the estimated global population based on the maximum count. Number in parentheses represents the number of counts on which the 1% threshold level was met or surpassed.

[2] Figures represent the number of counts which met or surpassed the Sub-regional IBA level (0.5% threshold) for southern Africa (Barnes 1998) but did not surpass the 1% global threshold level.

[3] Value represents the % of estimated provincial population and based on the maximum count. Sourced from Coordinated Waterbird Counts, Animal Demography Unit, unpublished data (2006)

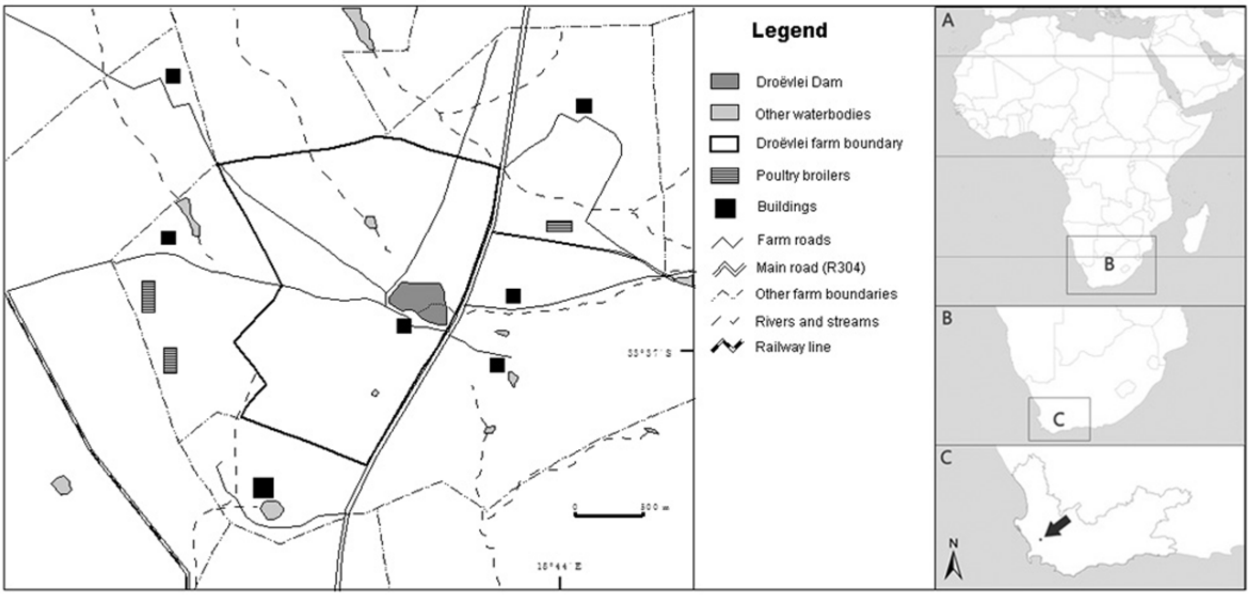

Figure B.1 Droëvlei Dam showing surrounding farmland boundaries and other waterbodies.

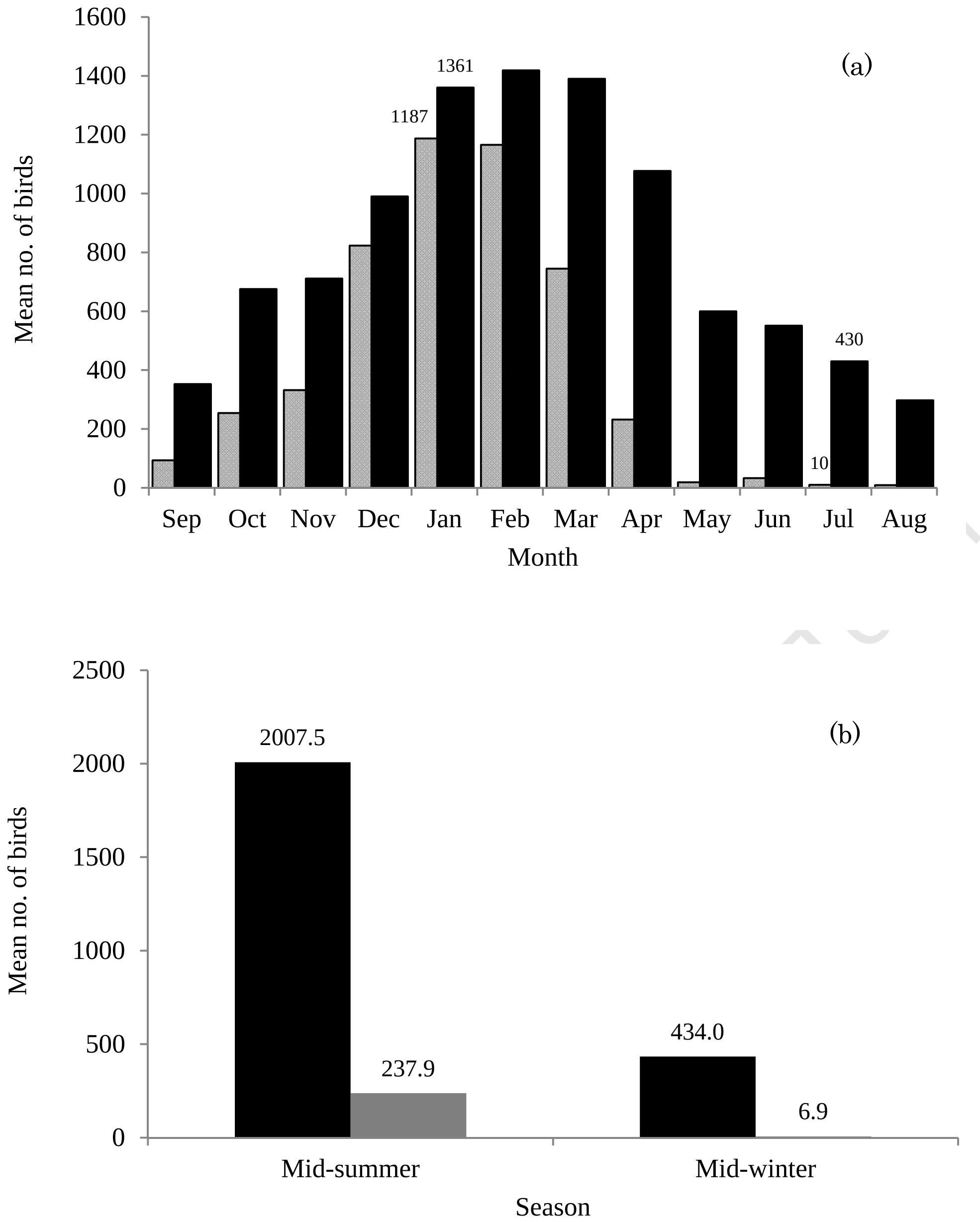

Figure B.2. Mean seasonal abundance of residents (black bars) and Palearctic migrant waterbirds (grey bars) at Droëvlei Dam from (a) 1985–1990 and (b) 1995–2006. The 1985–1990 data are based on monthly surveys and the 1985–1990 data are based on six-monthly counts with mid-summer representing January and mid-winter July. Numbers above each bar represent actual mean counts.

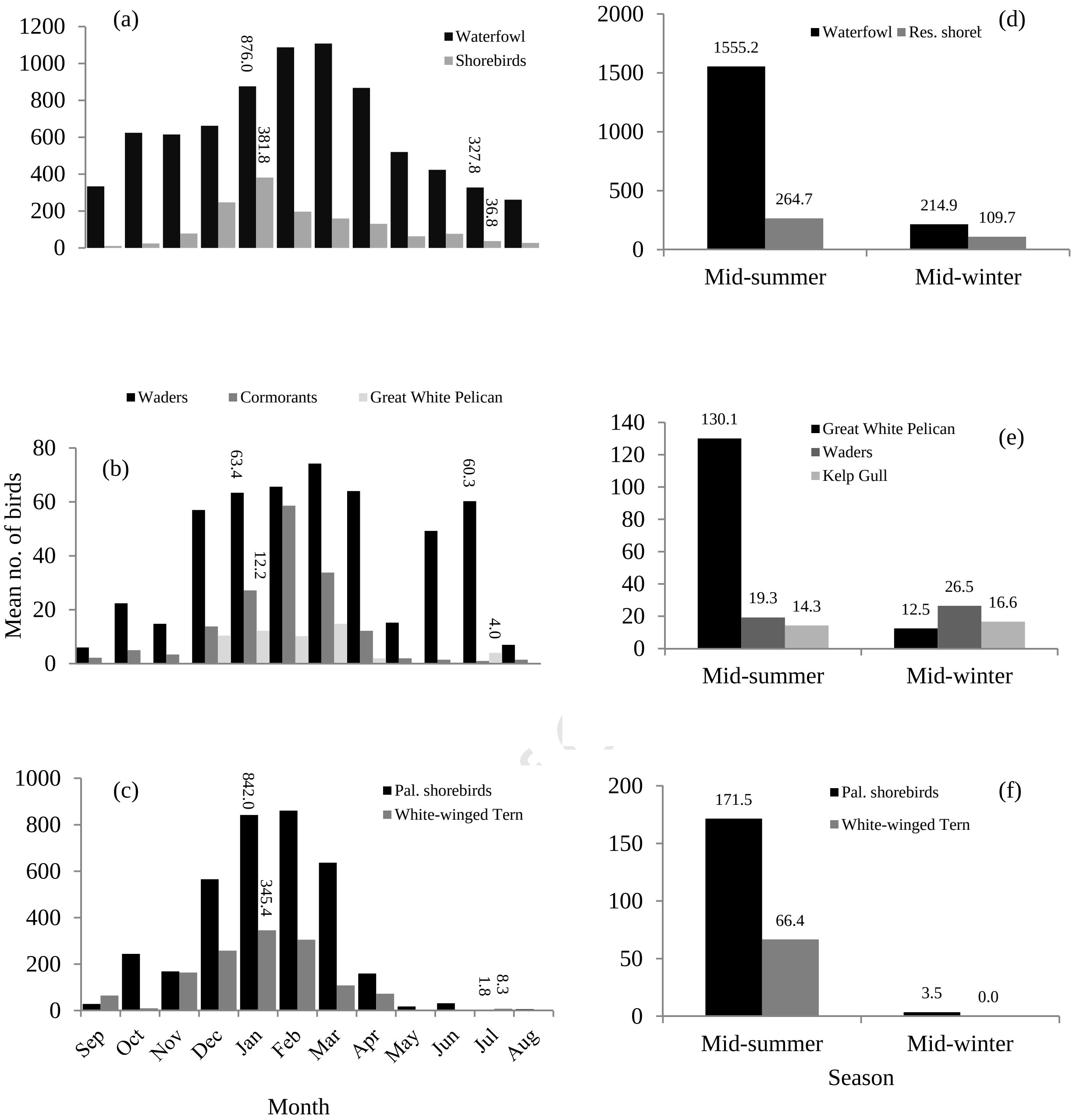

Figure B.3 Mean seasonal abundance of the major waterbird groups at Droëvlei Dam based on monthly seasonal data from 1985–1990 (a, b and c), and on six-monthly data from 1995–2006 (d, e and f). Figures above bars in (a), (b) and (c) indicate the corresponding value to the mid-summer and mid-winter of the six-monthly surveys.

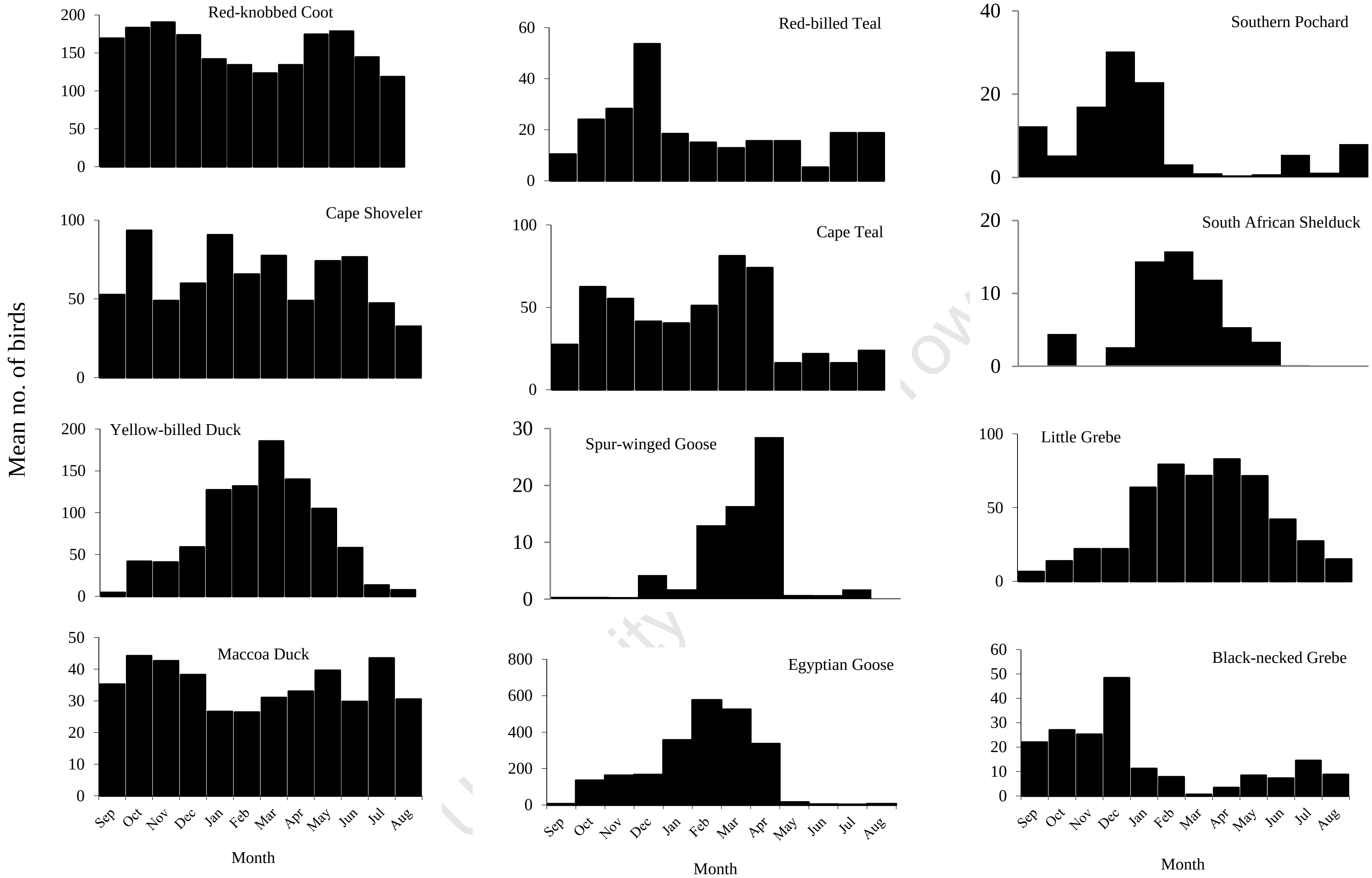

Figure B.4 Mean monthly abundance of 12 waterfowl species at Droëvlei Dam based on monthly survey data from 1983–1990.

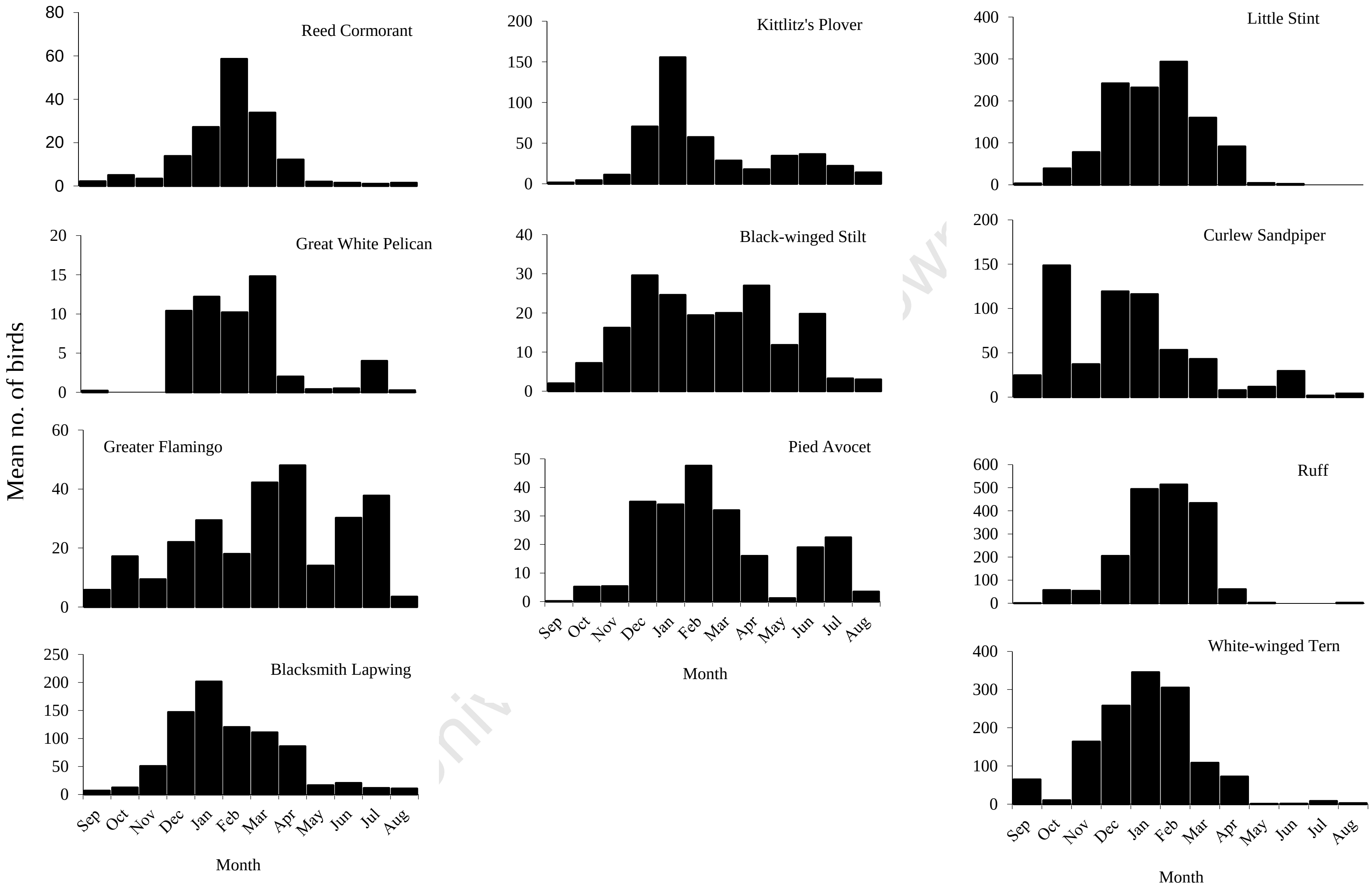

Figure B.5 Mean monthly abundance of selected resident and Palearctic waterbird species at Droëvlei Dam based on monthly survey data from 1983–1990.

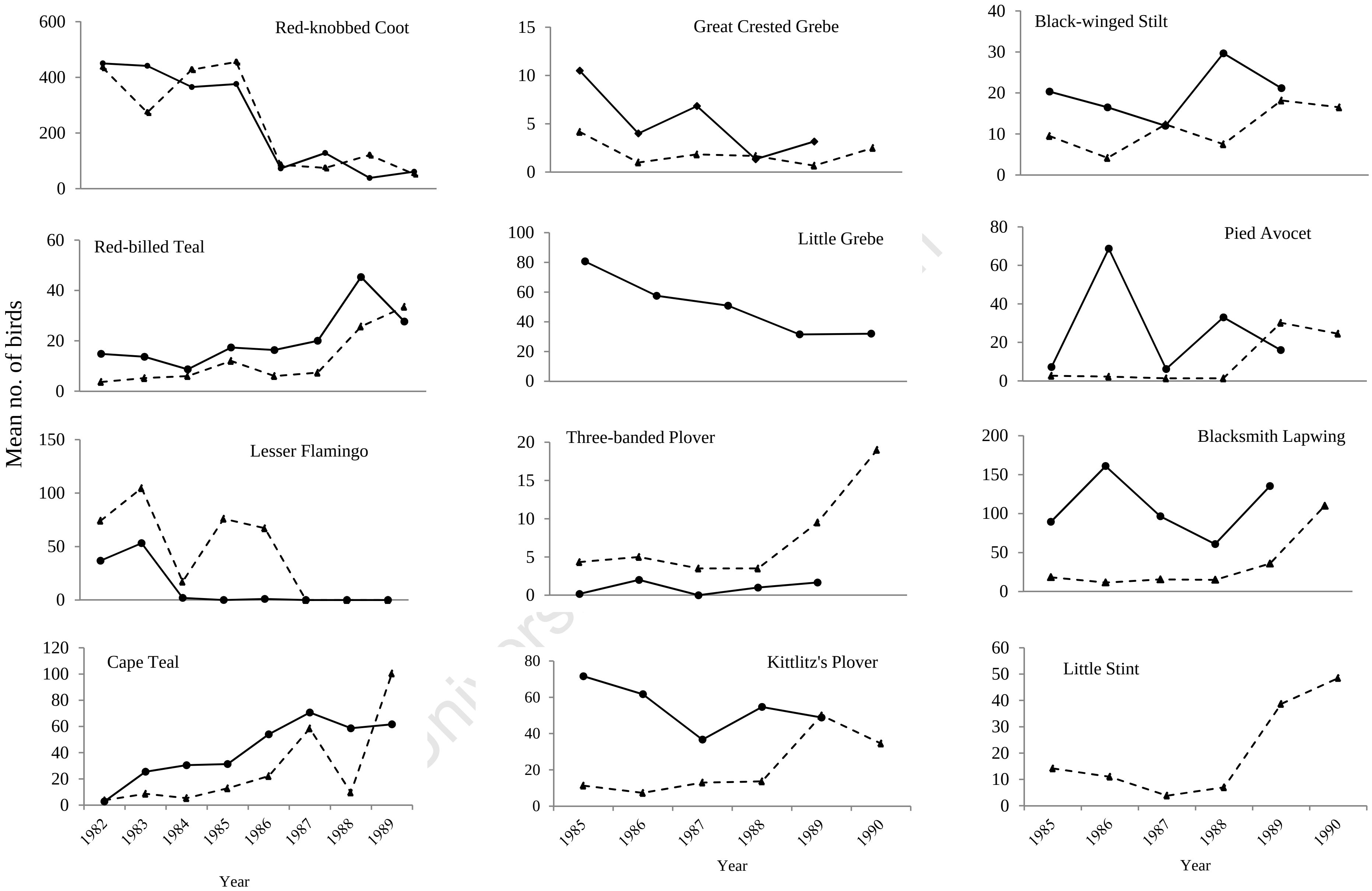

Figure B.6 Inter-annual mean seasonal abundance of selected resident and Palearctic waterbird species at Droëvlei Dam based on (a–d) monthly survey data from 1982–1990.

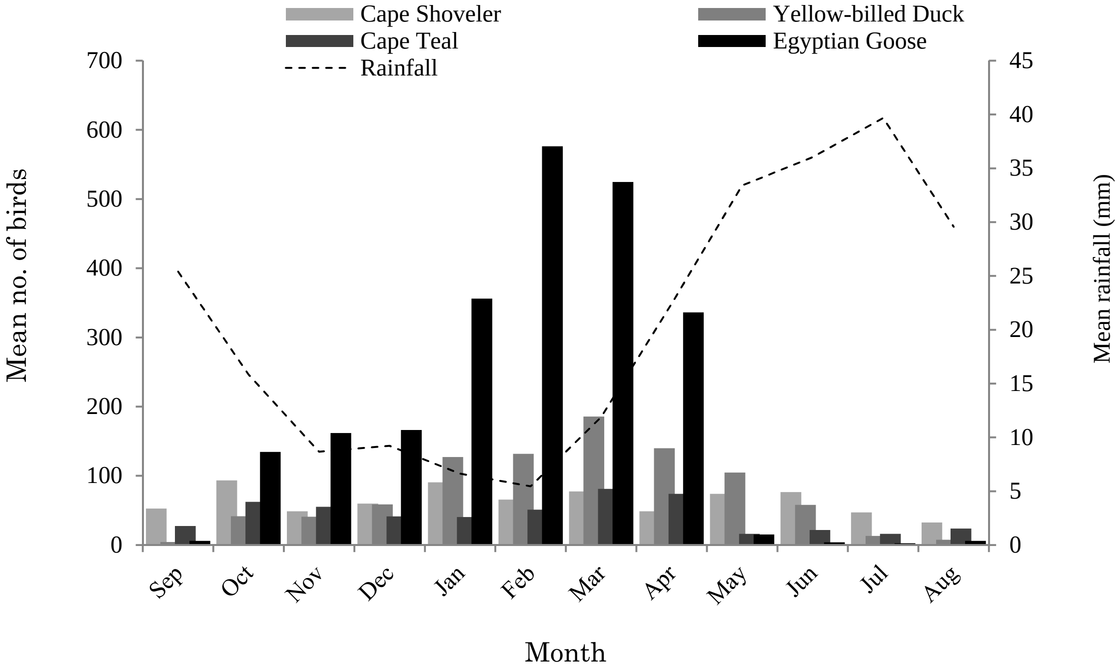

Figure B.7 Relationship between rainfall and the mean monthly abundance of five waterfowl species at Droëvlei Dam, 1985–1990.

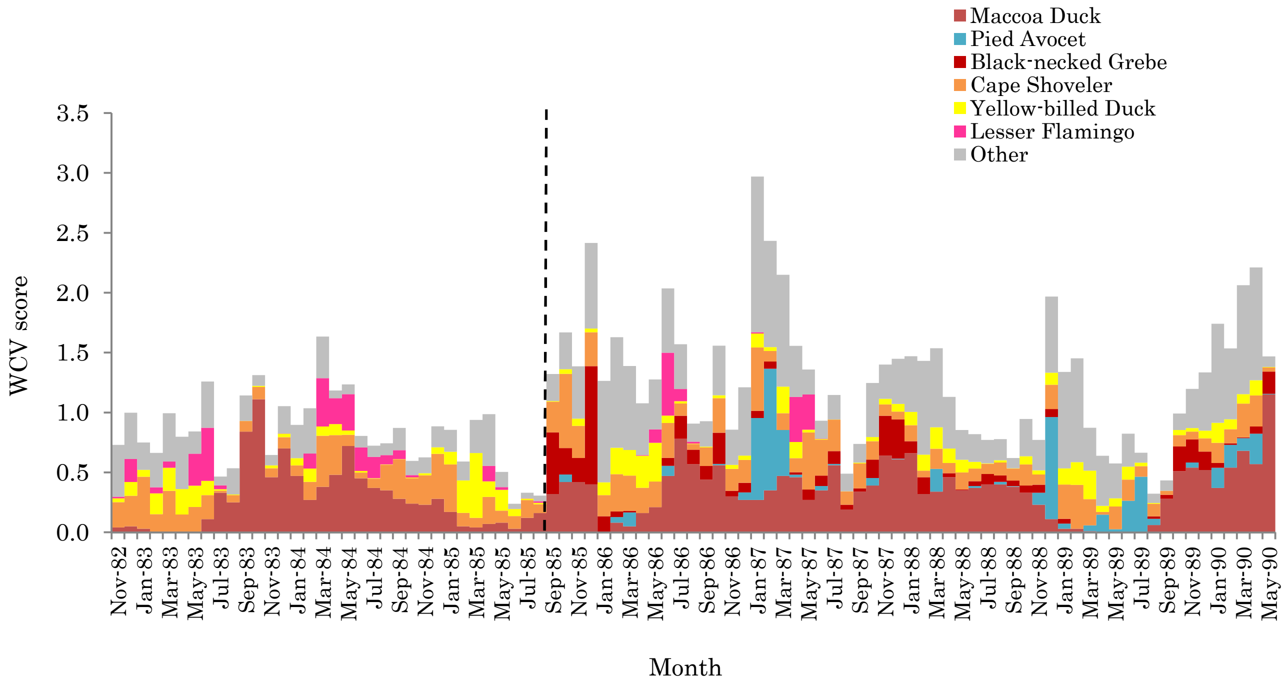

Figure B.8 Monthly Waterbird Conservation Value (WCV) scores at Droëvlei Dam from November 1982–May1990. The dotted line indicates the date (September 1985) from which all waterbird species were included in the calculation of the score.

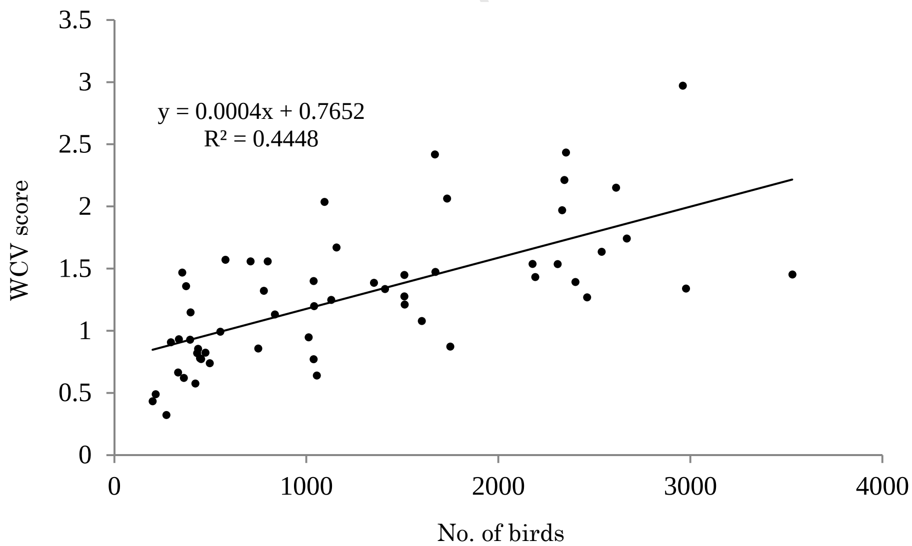

Figure B.9 Relationship between abundance and the Waterbird Conservation Value (WCV) score at Droëvlei Dam between September 1985 and May 1990.

Appendix C

Seasonality, trends and conservation status of waterbirds at an arid west coastal wetland in South Africa: Rocher Pan, 1979–2004

Abstract

An analysis of the waterbirds at Rocher Pan, a seasonal west coast wetland in South Africa, was carried out from 1979–2004. A total of 78 waterbird species (60 resident species and 18 migrant species) were recorded and up to 8 239 individuals were surveyed during this period. Occurrence patterns were strongly seasonal and mirrored the yearly seasonal rainfall and inundation pattern – mean summer abundance was 3 197 ± 2 731 birds and mean winter abundance 1 531 ± 1 714 birds. Waterfowl (ducks, geese, grebes, coot and moorhen) dominated the waterbird community and on average, they comprised 41.9% and 54.3% of the summer and winter waterbird abundance. Egyptian Goose and South African Shelduck were the only resident species that showed significant population increases during summer. Black-necked Grebe showed declining populations during winter. Palearctic migrants comprised about 20% of the waterbird community during summer. A total of 14 species surpassed the global 1% threshold levels; Cape Shoveler and Hartlaub's Gull dominated this group. Seven threatened species were recorded of which the Greater and Lesser Flamingo were the most important. The site qualifies for Ramsar and Important Bird Area (IBA) status. Aspects relating to rainfall, climate change and biological impacts on the wetland are also discussed.

Plate C.1 View looking north over Rocher Pan from where the Papkuils River enters the pan. The fynbos vegetation around the margins of the waterbody can be seen in the foreground. The white dots in the water represent Greater Flamingos. Photo: DM Harebottle

Introduction

The western coastal plain of South Africa falls within the western coastal slope region and is divided into a Mediterranean zone and an arid zone (Cowan 1995, Chapter 1). The boundary dividing the zones lies south of the Olifants River estuary (Figure 1.4, Chapter 1). The arid zone to the north has sparse vegetation cover and generally experiences a warm and dry climate throughout the year with rain falling during the winter (June–August). The Orange River estuary and Olifants River floodplain are the only extensive wetlands in the region, interspersed with small coastal pans and salt-marshes that are flooded by erratic and infrequent rainfall (Cowan 1995).

The Mediterranean zone lies to the south of the Olifants River estuary and although it has hot dry summers, winters are generally cooler and wetter. There are more extensive natural wetlands in this zone, including: Jakkalsvlei, Verlorenvlei, Rocher Pan, Berg River estuary and Langebaan Lagoon (Figure 1.4, Chapter 1). The Clanwilliam Dam is the only large impoundment in this region. Rocher Pan lies close to the boundary of the two zones (Figure 1.1). The Pan is an extinct estuary which is now one of two seasonal lakes in this region, the other being Wadrif Saltpan (Williams et al. 2002).

Rocher Pan was proclaimed a nature reserve in 1967 (Wessels 1997) primarily to provide a sanctuary for waterfowl and in particular the Cape Shoveler (du Preez 1992), a species endemic to southern Africa (Hockey et al. 2005). The species was known to occur at Rocher Pan regularly in globally significant numbers (Siegfried 1965) and the pan was regarded as being one of a few sites in southern Africa that was important to the ecology and conservation of the species (Heÿl 1985).

The first documented waterbird surveys at Rocher Pan were conducted by Brand (1961) who largely focused on waterfowl and breeding productivity. Shorebird surveys were carried out at Rocher Pan by Summers et al. (1976) as part of a larger wader survey of the Western Cape and some anecdotal information and ad hoc counts exist in unpublished reports (e.g. Coetzer et al. 1985, Underhill and Cooper 1982) but these have been far from comprehensive. In 1979 systematic surveys were initiated to provide primarily information on waterfowl abundance as part of a provincial programme to set hunting quotas and bag limits (Heÿl et al.1993). The waterbird data from these surveys remain largely unpublished and to date, there has been no review of the overall occurrence, abundance and conservation importance of waterbirds at the pan.

In this paper, I describe the status and abundance of waterbirds at Rocher Pan based on surveys conducted from 1979–2004 and assess the impact of rainfall on patterns of occurrence and abundance of a number of focal species. I also review the conservation value of the site for waterbirds and assess the critical importance of the site for Cape Shoveler since the proclamation of the reserve.

Study area

Rocher Pan (32°36'S, 18°18'E) is situated about 150 km north of Cape Town and 12 km from Dwarskersbos. It is located behind a ridge of coastal dunes about 500 m from the ocean at an altitude of about 3 m.a.s.l. (Wessels 1997) (Figure C.1). The waterbody is fed by two main inlets: the Papkuils River in the south, and the Sout River, further to the north. The Papkuils River which has its source in the mountains east of Aurora, 25 km to the east, passes through mainly arable land where wheat is grown. The pan has no outlet. Originally the waterbody was connected to the sea before the mouth of the Papkuils River was diverted and closed off by a local farmer in the mid-1800s to provide freshwater for livestock, and has remained in this freshwater-state for over 150 years (Coetzer 1981). Additional inundation occurs directly from rainfall and smaller local inlets.

When full, the pan is approximately 6.5 km long and 0.4 km wide and covers a surface area of approximately 110 ha; the mean depth is 0.5 m with a maximum depth of *c.* 2 m in the southern part of the pan (Coetzer 1981). Up to 20 small (< 1 ha) vegetated islands occur in the pan when it is fully inundated; three islands were initially constructed in 1968 to encourage breeding of waterfowl with the last island being formed in 1977 (du Preez 1992). Most of the vegetation on the islands consists of *Atriplex numularia* (Oumansoutbos), and *A. bolusii* (Soutbos). *Sarcocornia natalensis* (Brakbos) was planted on a few islands in 1974. *Juncus acutus* (Spiny Rush) spread naturally and is regularly cut-back (du Preez 1992)

The majority of the pan is incorporated into the Rocher Pan Nature Reserve; a small portion (*c.* 10ha) extends beyond the northern boundary of the reserve into private farmland. The reserve is 914ha in area and is administered by CapeNature (du Preez 1992). The nature reserve falls in the West Strandveld Bioregion (Mucina and Rutherford 2006), and the vegetation comprises mainly dune thicket with the *Eragrostis cyperoides* (sedge grass) *Chrysanthemoides monilifera* (Bietoubos) and *Willdenowia striata* being dominant species. The adjacent ocean stretch was proclaimed a marine reserve in 1988 (du Preez 1992).

The pan is located in the north-western region of the winter-rainfall region (WRR) of South Africa and is situated close to the desert and semi-desert climatic zone (Figures 1.1 and 1.4, Chapter 1). The area receives on average 230 mm of rain per annum (du Preez 1992). The pan usually fills during the start of the rainy season in May and June, July and August are the wettest three months. Water-levels recede during the drier summer months when inflow is reduced, precipitation is low and evaporation levels are high. The pan usually dries out between February–March each year depending on the amount of inundation during the previous winter rainfall (Coetzer 1981, du Preez 1992) and during very wet years it does not dry up completely before the next rainfall season (Coetzer 1985). The water in the pan is predominantly fresh but can become brackish during periods of low-water levels when salinities tend to increase (Coetzer 1981).

The dominant aquatic macrophytes are *Potamogeton pectinatus* and *Chara globularis* which occur throughout the greater part of the pan but do vary in density relative to salinity levels. The floor of the pan is dominated by two species: *Salicornia meyeriana* and *Sporobolus virginicus*. Emergent vegetation occur mainly around the fringes of the waterbody and are dominated by *Juncus acutus, Scirpus maritimus* with some large scattered patches of *Phragmites australis*, the latter an invader species (Wheeler 1998).

Methods

Waterbird surveys were conducted almost monthly from June 1979 to July 2004. Surveys were carried out mostly in the morning or early afternoon and lasted between 2–3 hours. Although observers varied during different periods throughout the survey period, the routes used by observers remained consistent which reduced observer bias. Species coverage varied between the periods. Nineteen species (pelicans, flamingos, ducks, geese and coots) were counted regularly from June 1979–August 1985 (Table 1) while an additional 50 species, constituting a broader definition of waterbirds, were regularly counted from September 1985–July 2004 .

Waterbirds are defined in Chapter 1 and vernacular names follow those given in Hockey et al. (2005). Species were divided into southern African residents and Palearctic migrants (Appendix 1.2, Chapter1). Seasonality, abundance and trend analyses follows closely that of Appendix A. Overall waterbird abundance and diversity was assessed for the period September 1985–July 2004 when all waterbird species were surveyed. Trend analyses for the anatids, grebes, Red-knobbed Coot, Great White Pelican, Greater Flamingo and Lesser Flamingo were based on the surveys from April 1979–July 2004; inter-annual variation for all other species were based on the period June 1985 – July 2004. Emphasis is placed on the 16 species counted during the SAWC due to the duration and consistency of the surveys which reflected more meaningful seasonal patterns and aided interpretation of long-term trends.

The conservation importance of Rocher Pan was assessed based on the Waterbird Conservation Value (WCV) score (Chapter 2). Methods for the calculation of this score are described in Chapter 2 (see Methods). Scores were calculated for each month between

1985–2004 when all waterbirds were surveyed at the pan. An overall score for the entire site was also calculated. To assess sub-regional importance the 0.5% index was used based on the sub-regional IBA thresholds in Barnes (1998). The proportion of counts for species comprising 5% or more of the estimated Western Cape population were also computed to gauge the site's significance at a provincial level.

Results

Overall waterbird abundance and richness

A total of 273 surveys was carried out between June 1979 and July 2004 and covered a total of 78 species. Of these, 16 species were surveyed during the whole study period, while an additional 62 were surveyed from September 1985–July 2004 (n = 201 surveys) (Table C.1). Of the 273 surveys, 141 surveys were carried out in summer, and 132 during winter, while 105 summer surveys and 96 winter surveys constituted the 1985–2004 period.

Numbers of waterbirds at Rocher Pan ranged between 0 and 13 708 (November 1994). The mean summer count was double (3 197 ± 2 731 birds) that in winter (1 531.3 ± 1 714 birds) (Table C.1). Species richness was higher in summer ($\bar{x}$ = 58) than in winter ($\bar{x}$ = 44); November on average held the most species (n = 67) and May the least number (n = 37). The mean number of waterbirds counted per month ranged between 101 in April and 3 234 in November.

Overall, the summer surveys were dominated by seven species which made up more than 70% of all waterbirds at the site: Red-knobbed Coot (21%), Curlew Sandpiper (14%), Greater Flamingo (11%), Cape Shoveler (9%), unidentified Palearctic shorebirds (8%), Little Stint (5%) and White-breasted Cormorant (4%). The winter surveys were dominated by Red-knobbed Coot (31%), Greater Flamingo (15%), Cape Shoveler (10%), Hartlaub's Gull (5%) and Black-necked Grebe (4%) which made up 65% of all waterbirds at the site during winter.

The overall annual pattern of occurrence of waterbirds was strongly seasonal at the pan; abundance of waterbirds increased from June ($\bar{x}$ = 835) and peaked during November ($\bar{x}$ = 5 993). Numbers then generally declined from January with the lowest numbers of birds recorded during April ($\bar{x}$ = 161). Over a period of five months there is an almost 40–fold decline in the number of waterbirds at the pan (Figure C.2).

Waterfowl (ducks, geese, grebes, coot and moorhen) dominated the waterbird community. On average, they comprised 41.9% and 54.3% of the summer and winter waterbird abundance (Table C.1). The guild showed marked seasonality. Numbers peaked in October ($\bar{x}$ = 2 842) and November ($\bar{x}$ = 2 692) with sharp declines from December–April before showing increases from June onwards (Figure C.3). Palearctic shorebirds comprised

23.7% of the waterbirds during summer and dominated the entire shorebird community from October–March (Figure C.3).

Overall, numbers of resident shorebirds were higher in summer ($\bar{x}$ = 243 ± 225) than in winter ($\bar{x}$ = 111 ± 109) (Table C.1). Abundance peaked in October ($\bar{x}$ = 423) and decreased until January with a small resurgence in February (Figure C.3). Small numbers (< 50 birds) occurred monthly from April to August and then increased from July–September (90–285 birds, Figure C.3). This group contributed 7% to the total waterbird community in both summer and winter.

Flamingos and waders both showed seasonal occurrence with most birds occurring from September–December (Figure C.3). Resident gulls showed less pronounced seasonality with relatively stable numbers from June–November ($\bar{x}$ = 175 birds); March and April were the only months when numbers declined substantially (Figure C.3). Resident terns generally occurred in small numbers (Table C.1) and were most abundant in June–August with most birds occurring in August ($\bar{x}$ = 91). Palearctic terns peaked in September ($\bar{x}$ = 191) and occurred in varying numbers until March ($\bar{x}$ = 7).

Residents versus migrants

Residents comprised 60 species, the remaining 18 species being Palearctic migrants. On average there were double the number of resident birds than Palearctic migrants during summer; only February and March showed a near-equal ratio of the two groups (Figure C.2). Most migrants departed in April and residents dominated during winter, although some over-wintering Palearctic migrants were present during the winter period (Figures C.2 and C.3).

Ducks and geese

The anatidae was one of the dominant groups at Rocher Pan and comprised, on average, 38% and 54% of the waterbird community during summer and winter respectively. When considering only the resident waterbirds these figures rose to 56% and 57% respectively.

Egyptian Goose numbers peaked in November (maximum 660 in November 1994). Numbers then decreased from December with generally fewer than five recorded from February to May; numbers increased from June (Figure C.4).

Numbers of Cape Shoveler showed annual peaks from October–November. From 1990–1995 peak numbers exceeded 1 000 birds with a maximum of 1 610 birds recorded in October 1990. Yellow-billed Ducks started increasing in abundance in June and numbers peaked in October (maximum 1 131 in October 1991). They were generally absent from the pan March–May (Figure C.4). South African Shelduck numbers increased during late winter and early summer and numbers peaked in October (285 in October 1992). Numbers remained stable from October–January and declined by 50% in February; less than five birds on average were present in March and April. Red-billed Teal and Cape Teal showed similar abundance patterns with highest numbers present from September–December. Overall, Cape Teal numbers peaked in October (1 069 in October 1990) and numbers of Red-billed Teal usually peaked in November, but had a maximum of 836 in October 1990.

Grebes

The Little Grebe and Black-necked Grebe showed similar patterns of occurrence; both, on average, increased from June–August, peaked in September and then decreased from November –December. They were absent from the pan from January–May (Figure C.4). Black-necked Grebes were generally more abundant than Little Grebes; during peak occurrence times (August–October), there were generally twice as many Black-necked Grebes as Little Grebes. Maximum numbers were of 661 Black-necked Grebes recorded in September 1990 and Little Grebe numbers reached their maximum (298) in November1995.

Red-knobbed Coot

Red-knobbed Coot, like most of the ducks, increased in late winter (July–August). Numbers then peaked from September–November; with a maximum of 6 259 birds in November 1992. From November–December there was a 48% reduction in numbers of coot with a further 61% reduction from December–January (Figure C.4). They were virtually absent from the pan between February and May with small numbers (< 15 birds) being recorded, on average, during March and April.

White-breasted Cormorant

The White-breasted Cormorant was the only phalacrocoracid that occurred in numbers at Rocher Pan. Their pattern of occurrence resembled that of most other waterbirds; numbers increased in late winter (August–September) then doubled during October and peaked in December/January, with a maximum of 772 in January 1989). A rapid exodus then took place and birds left Rocher Pan from February and started returning in May and June (Figure C.5).

Waders

Four species are considered here. African Sacred Ibis occurred mainly between August and December; numbers generally peaked in September–October, with a maximum of 578 in August 1993, and less than 15 birds were recorded from January–July (Figure C.5).

Contrastingly, Glossy Ibis occurred from October to January with peaks in December, with a maximum of 130 in December 1997. Fewer than two birds, on average, were recorded from January–September (Figure C.6).

Both Greater Flamingo and Lesser Flamingo occurred throughout the year; the Greater Flamingo occurred in larger numbers (Figure C.5). Greater Flamingos started arriving in June and peaked in September–October, with a maximum of 4 239 in October 1995. Numbers declined by 50% each month between November–January and the species was mostly absent from February–June, with fewer than 50 birds, on average, being recorded (Figure C.5). Lesser Flamingos, on the other hand, started arriving in August and increased thereafter, with two peaks: one in October and one in February (max. 1 082 in October 1995). They were present from March–July in low numbers (< 30 birds on average) (Figure C.5).

Resident gulls and terns

Kelp Gull, Hartlaub's Gull and Swift Tern dominated this group, with Kelp and Hartlaub's Gull comprising 95% of all resident larids at Rocher Pan. Overall the group showed higher abundance in winter (164.6 ± 124) than summer (118.7 ± 87) and numbers peaked June–August (mean 279 birds in August) (Table C.1, Figure C.5). Kelp Gull tended to dominate in summer (mean 67.8, max. 953 in January 1989) and Hartlaub's Gull in winter (mean 82.4, max. 571 in July 2002) (Table C.1, Figure C.6). Hartlaub's Gull also showed a stronger seasonal pattern of occurrence while Kelp Gull numbers fluctuated throughout the year although numbers of both species tended to decline during March and April (Figure C.5).

Swift Tern was the only tern species that occurred in large numbers and showed any real pattern of occurrence. They occurred mainly in winter (mean 29.4 ± 30.5) with less than five birds on average during summer. Numbers peaked from June–August (max. 435 in August 1995) with mean counts of 80 birds being recorded during August. Less than 20 birds were present during the remaining months of the year (Figure C.5).

Resident shorebirds

This group was dominated by Black-winged Stilt and Kittlitz's Plover; each species contributed 71% and 83% to the resident shorebird population in summer and winter respectively. Black-winged Stilt numbers peaked in October, with a maximum of 868 in October 1994, and most birds departed by January (Figure C.6); from January to July less than 30 birds on average were recorded each month with March and April recording less than 5 birds. In contrast, numbers of Kittlitz's Plover peaked from January–March (max. 368 in February 1995). Numbers then stabilized from April–December and averaged 25 birds per month (Figure C.6).

Other species that occurred in numbers large enough to allow meaningful interpretations were Pied Avocet, Blacksmith Lapwing and African Black Oystercatcher. Pied Avocet numbers were larger in summer (mean 37.6 ± 23.2) than winter (mean 1.1 ± 1.2) and peaked from December–February, with a maximum of 715 in December 1995. They were largely absent between April and September (Figure C.6). Blacksmith Lapwing tended to more abundant in summer (21.5 ± 13) than winter (13.1 ± 9) and numbers peaked from October–December, with a maximum of 147 in October 1990; fewer than five birds on average occurred between March and May (Figure C.6).

African Black Oystercatcher were more abundant during winter (10.2 ± 4.6) than summer (4.2. ± 3.2) and peaked from June–September, with a maximum of 33 in June 1998. There were fewer than five birds on average from December to April (Figure C.6).

Palearctic shorebirds

This group showed the normal annual pattern of Palearctic migrants with large numbers during summer and few birds during the winter; summer means of 1 048.2 ± 825 were recorded compared with 52.9 ± 100 during winter (Table C.1, Figure C.6). Of the 18 species recorded, four dominated this group: Curlew Sandpiper (63%), Little Stint (23%), Ruff (10%) and Marsh Sandpiper (3%) (Table C.1). Overall, birds started arriving in September and had departed by April (Figure C.6).

All four species peaked from October–December; Curlew Sandpiper (max. 5012 in November 1995), Little Stint (1 243 in November 1993), Ruff (max. 600 in December 1987) and Marsh Sandpiper (max. 276 in December 1995). Little Stint showed the greatest stability with about 200 birds present from November–February. All four species had small numbers (< 20 birds) during the winter period (Figure C.6).

Palearctic terns

Three species were recorded at Rocher Pan during the austral summer:- White-winged Tern, Common Tern and Sandwich Tern. White-winged Tern was the most abundant ($\bar{x}$ = 48, Table C.1). Their numbers peaked in September (max. 1662 in September 1998) but showed some fluctuations in abundance from September–December; a small number (c. 20 birds) were recorded from June–August (Figure C.7). Common Tern and Sandwich Tern both occurred in small numbers during summer ($\bar{x} < 10$ birds), although a maximum of 163 Common Terns were recorded in October 1986). The majority of Common Terns had left Rocher Pan by December, and some birds (< 5) were observed during winter months

(Figure 6). Numbers of Sandwich Terns were small (< 5 birds/month) but interestingly most records occurred from June–August.

Inter-annual variation in abundance and trends

Residents

Trends are presented for 22 species: 10 waterfowl species, five shorebird species, Greater Flamingo, Lesser Flamingo, Hartlaub's Gull, Kelp Gull, African Sacred Ibis, White-breasted Cormorant, and Swift Tern (Figures C.7, C.8, C.9 and C.10). Other species are omitted as they occurred in too small numbers for any meaningful interpretation to be made.

For waterfowl, significant increases in summer populations were evident for Egyptian Goose ($r = 0.45$, $p < 0.05$) and South African Shelduck ($r = 0.47$, $p < 0.01$). Black-necked Grebe was the only waterfowl species to show significant declines in both summer ($r = –0.49$, $p < 0.01$) and winter ($r = –0.41$, $p < 0.05$). The remainder showed large annual fluctuations and no real trends were evident (Figure C.7). Interestingly, some species tended to peak simultaneously (e.g. South African Shelduck, Cape Shoveler and Red-knobbed Coot in 1992/93, Red-billed Teal and Cape Teal in 1990/91, and Cape Shoveler and Egyptian Goose in 1995/96; Figure C.7).

Both flamingo species showed considerable inter-annual fluctuations. Greater Flamingo numbers at the pan tended to remain stable overall and numbers only peaked during the summer of 1995/96 (mean of 1 484 birds). No definite trend could be described. Lesser Flamingo had more frequent peaks (1979/80, 1992/93, 1995/96 and 1998/99) although these were smaller (< 250 birds) compared with Greater Flamingo (Figure C.8). Interestingly the annual winter fluctuation for Greater Flamingo mirrors that of the summer pattern, while for Lesser Flamingo there is a contrasting pattern with a weak declining trend.

Inter-annual populations of Kelp Gull and Hartlaub's Gull during summer both revealed declining trends; Kelp Gull showed the strongest decline ($r = –0.62$, $p < 0.001$) over Hartlaub's Gull ($r = –0.41$, $p < 0.05$) (Figure C.8). Swift Tern showed no trend as inter-annual abundance revealed large fluctuations.

Summer and winter populations of White-breasted Cormorant and African Sacred Ibis fluctuated throughout the 18 year period. No trends were evident.

For shorebirds, the African Black Oystercatcher showed significant declines in summer ($r = –0.56$, $p < 0.01$) and winter ($r = –0.64$, $p < 0.001$) (Figure C.9). The only other shorebird that showed a significant trend was Kittlitz's Plover with a significant downward winter trend ($r = -0.48$, $p < 0.01$) (Figure C.9).

Palearctic migrants

Among the shorebirds inter-annual patterns were highly variable and no definite trends were discernable. Of the five shorebirds considered, Common Greenshank was the only species to show some evidence of increasing numbers during the study period ($r = 0.61$, $p < 0.001$), but numbers of birds were low (< 20 birds) (Figure C.9). Marsh Sandpiper and Curlew Sandpiper, were the only species that showed strong peaks during 1991/92 with small fluctuations during other years, while Ruff and Little Stint showed more frequent peaks with main peaks occurring during 1983/84 and 1989/90 respectively.

Annual occurrence and abundance at Rocher Pan fluctuated considerably for both White-winged Tern and Common Tern (Figure C.10). The terns tended to peak in alternative years or every other year and resulted in them being almost mutually exclusive at the pan. Common Tern have not been recorded or have been recorded in small numbers (< 5 birds) since the summer of 1990/91 and suggests a downward trend at the pan. Similarly, White-winged Terns have been recorded in fewer numbers (< 30 birds) since the summer of 1994/95 (Figure C.10).

Waterbird Conservation Value (WCV) scores

The monthly WCV scores for Rocher Pan between September 1995 and July 2004 are shown in Figure C.11. Inter-annual fluctuations were evident although the general pattern tended to suggest a steady rise in certain populations from May–September followed by a drop-off in numbers from December to March. Of all the surveys, 16 had scores of 10 or more, while only three counts (September 1990, October 1990 and October 1995) scored higher than 15. The median summer and winter scores were 5.2 and 2.6 respectively. From September 1990 to November 1995 at least one month each year scored 10 or higher; these months usually encompassed September, October and/or November. In contrast, from December 1995 to June 2001 no month surpassed a score greater than 10. From July 2001 to July 2004, only one month (August 2001) scored greater than 10 and only two months scored between 5–10.

A total of 14 species constituted those species that reached or surpassed the 1% threshold levels (Table C.2). Cape Shoveler and Hartlaub's Gull were the only species to have globally and regionally important numbers, their 1% indices supporting more than double the 1% threshold levels. The remainder all reached levels that represented more than 1% of the estimated southern African populations (Wetlands International 2006).

Seven species – White-breasted Cormorant, Caspian Tern, Greater Flamingo, Black-necked Grebe, Black-winged Stilt, Pied Avocet and Swift Tern – occurred at levels that surpassed at least double the 1% threshold for southern Africa. Not all of these species occurred regularly at these levels – only White-breasted Cormorant (27%), Cape Shoveler (25%), Greater Flamingo (15%) and Black-winged Stilt (14%) were counted at these levels on more than 10% of the counts. In terms of South Africa's Western Cape Province, Rocher Pan supports up to one-third of the Caspian Tern population, while Greater Flamingo, Black-necked Grebe and Cape Shoveler represented about 20% of their estimated provincial populations (Table C.2).

The relationship between the monthly WCV scores and (a) the number of species reaching or surpassing the 1% threshold levels, and (b) total number of birds are shown in Figures C.12a and C.12b respectively. These showed that although large scores (≥ 10) are usually associated with greater number of species reaching 1% threshold levels and/or larger number of birds, this was not always the case. On two occasions – January 1993 and August 2001 – WCV scores ≥ 10 occurred with a minimum of two species, while in August 2001 a score of 13.8 was recorded when a little over 1 000 birds were recorded. It is also interesting to note that although some counts did not contain species at 1% levels, the cumulative WCV score was above 1.

In terms of species maxima, Rocher Pan ranks as the fifth most important site for waterbird abundance among Western Cape wetlands in summer, where all major wetlands are surveyed (Coordinated Waterbird Counts, Animal Demography Unit, unpubl. data; Table A.5, Appendix A).

Threatened species

Rocher Pan supported seven Red Data species: African Marsh Harrier (Vulnerable) and six Near-threatened species – Greater Flamingo, Lesser Flamingo, Cape Cormorant, Great White Pelican, African Black Oystercatcher, Black Stork and Caspian Tern (Barnes 2000). The flamingos use the pan on an annual basis, the Greater more so than the Lesser, but nevertheless highlights the importance of this site in the species' critical site network within southern Africa (Simmons 1996, 2000, African-Eurasian Waterbird Agreement 2000). The Cape Cormorant, Great White Pelican and African Black Oystercatcher probably only make use of the site for feeding and/or roosting, while the Black Stork and African Marsh Harrier are probably rare, but annual, visitors to the pan (Table C.1).

Discussion

Seasonality and abundance

The results clearly show that the overall annual pattern of occurrence of waterbirds was strongly seasonal at Rocher Pan and mirrored the yearly seasonal rainfall and inundation pattern. The pan fills via increased inflow as a result of winter rains which tend to peak in July (Figure C.2). Numbers of waterbirds started to increase from August with maximum numbers occurring during October–November. This indicates that the pan starts to fill about one month after peak rains and that there is almost a three month delay before peak abundance occurs. Coetzer (1985) does indicated that depending on the level of rainfall and period of inundation it can take up to two months before most of the pan fills. The pan the starts to dry out from January onwards when inflow is nil or negligible and hot summer temperatures and strong south-easterly winds lead to high evaporation levels. By late March and through April the pan is usually dry or only has small pools of shallow water, the latter if late inundation occurs. Waterbird abundance drops rapidly during this period (December–March) and by April most waterbirds have moved off.

The seasonal, ephemeral nature of the pan is a key element of the wetland and defines how waterbirds, notably resident species, use the site. There are progressive stages in the pan's condition that favour some waterbirds over others. Thus, waterfowl prefer the pan when it is fully inundated (September–November), a time when it is largely unsuitable for shorebirds (see Figures C.5 and C.6). As it dries down from December onwards, so it becomes progressively less attractive to waterfowl and more attractive to shorebirds and waders; species such as Kittlitz's Plover, Pied Avocet, Blacksmith Lapwing, Greater Flamingo and Lesser Flamingo were more abundant making use of the remaining shallower standing water and exposed shoreline and mud-flats. When completely dry in April (and sometimes early May, Coetser 1985), the dried surface of the pan is used by species such as Kittlitz's Plover which become increasingly abundant (Figure C.6), and by gulls and terns as day roosts (AJ Williams pers. comm.).

During the draw-down phase adult waterfowl have to leave the pan well before it dries out as they undergo a month-long flightless post-breeding moult when they have to be at waterbodies that are permanent or at least remain reliably flooded and through a period of post-moult recovery. Heÿl et al (1993) found that for the Cape Shoveler in the winter-rainfall region numbers remained relatively high two months after their peak abundance and suggested this related to a period when birds recovered their body condition following their moult period.

Thus, it seems plausible that the period of inundation can determine the extent to which waterfowl utilize the site for breeding and moulting. In years of good rainfall and/or with late inundation the pan becomes optimal as a breeding and post-breeding moult and refuge site but in years of low rainfall and/or early inundation, drying is likely to occur sooner which could impact the way in which birds use the site as a breeding site and/or moult refuge. For the latter, fewer birds may choose to breed at the pan and finding alternative sites at which to breed becomes imperative. The fluctuations and variability seen in the inter-annual seasonal abundance of all the waterfowl species provides some support for this, with certain years accommodating more birds than others (e.g. Red-knobbed Coot, Maccoa Duck, South African Shelduck, Cape Shoveler and Little Grebe in 1992/93 and Cape Teal and Black-necked Grebe in 1987/88). These peaks tend to suggest preferences for certain inundation regimes, the former being subject to high inflow resulting in primarily longer freshwater inundation and the latter probably from low- or reduced flow periods causing more saline conditions to develop. The inter-annual rainfall at Elandsbaai weather station tends to suggest that this was the case in the respective years. But this station monitors coastal rain about 35 km to the north of Rocher Pan and would not accurately capture the variability in inflow in the Papkuils River. However, it seems clear that proximal factors such as rainfall and inundation patterns determine the seasonal occurrence of ducks and geese at Rocher Pan.

Inter-annual variation, emigration and immigration

Most species showed no clear trend and fluctuations between years tended to be the rule rather than the exception. Some species did tend to show some increases: Egyptian Goose and South African Shelduck were the only resident species whose numbers, on average, have shown increases over the 23 years. Common Greenshank and Little Stint were the only Palearctic species tended to show increases over the study period, although the Common Greenshank occurred in small numbers (< 10 birds) and the trend may not relate to a true increase.

As an ephemeral system emigration and immigration occurs at pivotal points during the year. As the pan fills at the start of the winter rainfall season (June–July) primary productivity starts to increase (Coetzer 1981) which attracts mostly waterfowl and gulls to the pan (Figure C.3). Resident shorebirds tend to be largely absent due to the high water-levels and lack of shoreline during this period. By October and November peak abundance occurs and includes large numbers of waders, flamingos and Palearctic shorebirds. From January–April, during the dry spell when production in the pan is low and water-levels recede, most waterbirds, and notably the waterfowl, emigrate to find permanent, deep water. Thus, Rocher Pan exhibits a constant annual influx-exodus cycle. This cycle, as evidenced by the inter-annual abundances, is never static and arrival and departure times will depend on the inundation patterns from one year to the next. The Berg River Estuary and Verlorenvlei are possible emigration localities for Rocher Pan's waterbirds as they lie in close (< 30 km) proximity to the pan and provide optimal habitats when the pan dries up. How site-faithful some species are to Rocher Pan is unknown but it is assumed that at least a large proportion of the breeding waterfowl and possibly gulls and terns return to the pan every year.

The pan could support nomadic wetland birds that make use of temporary wetlands in the arid zone further north and immigration could contribute to smaller influxes. It is well established that to breed, flamingos need flooding of large pans in Botswana and northern Namibia and are forced to alternative, mainly coastal wetlands when the interior pans dry out (Williams and Velásquez 1997). Any temporary influxes of waterbirds from areas to the north of Rocher Pan would be dependent on the amount and frequency of rainfall in the arid zone. Other nomadic species such as the Pied Avocet and Black-winged Stilt are known to move around in response to changing conditions at wetlands or through their wandering movements in the landscape and may only return to Rocher Pan in large numbers in certain years (Figure C.6). Nevertheless, these immigration events highlight the inter-connectivity between sites and macro-use of landscape by waterbirds in this part of the winter-rainfall region. Ringing studies could elucidate this interconnectivity.

Relationship of wetness to occurrence of waterbirds at Rocher Pan

Overall, the seasonal abundance and inter-annual variation of waterbirds at Rocher Pan can be seen in light of two intrinsic factors, water-level fluctuations at the pan and regional rainfall. Because water-level fluctuations in the pan are dependent on rainfall in the catchment and direct rainfall, there should be a relationship between accumulative rainfall (wetness) and waterbird occurrence at the pan. Thus besides the actual seasonality of rainfall which will determine the months in which inundation is likely to occur, the actual response to this inundation is what is being defined here.

This relationship could be modeled for each species using generalised linear models with log-link functions with seasonality and wetness as explanatory variables. Similar studies were carried out by Chambers and Loyn (2006) in Australia who found positive relationships between seasonal patterns of abundance of Black Swan *Cygnus atratus*, White-faced Heron *Egretta novaehollandiae* and Grey Teal *Anas gracilis* with local climatic variables such as streamflow and regional rainfall as well as broader climatic influences such as the Southern Oscillation Index. They discovered time-lag responses for each species based largely on stream flow variability and highlighted that waterfowl, in particular, respond to climatic events at broader landscape or even continental scales, and require habitats in widely different places and different times for different purposes. There is a need to conduct similar waterbird–climatic studies in South Africa to determine exactly how waterbirds respond to local and regional climatic patterns particularly in light of wetland seasonality and rainfall regimes between the winter and summer rainfall regions in South Africa.

Impacts of climate change

If the response to annual wetness is a primary factor governing how waterbirds, in general, use Rocher Pan, then long-term climate change needs to be considered. Climate change models for the Western Cape Province predict that the climate will be warmer and drier with a drying trend from west to east (Midgley et al. 2005). In addition, winter rainfall patterns are predicted to weaken with rainfall becoming more irregular but rainfall events more intense. These changes will have profound impacts on the wetland avifauna in the region particularly in the way waterbirds use certain sites. With changes to inflow periodicity, Rocher Pan could remain drier for longer periods and have short burst of productivity and this will impact on the occurrence of and use by waterbirds at the site. In the long-term, the larger and more permanent wetlands in the region, such as Verlorenvlei, Berg River Estuary and Langebaan Lagoon, could see influxes of waterbirds and become more important refuges for species that once utilized more temporary sites such as Rocher Pan. Continued long-term monitoring and more detailed climate change analyses are recommended for future assessment of the site's importance as a regional waterbird refuge.

Importance of Rocher Pan for waterbirds

The waterbird survey data presented here clearly demonstrated that Rocher Pan has more significance for resident African species than Palearctic migrants. Of the 14 species that had globally significant populations, 13 species were African residents; the only Palearctic species was the Curlew Sandpiper (see Table C.2). Although Palearctic migrants do not generally occur in significant numbers the site does offer these species a feeding and roosting refuge along the East Atlantic Flyway, particularly on arrival (September– October) and when water-levels recede (December–February).

Breeding birds

I did not assess breeding status in this chapter as I did not have access to the breeding data. However, Heÿl et al. (1993) summarized waterfowl breeding outputs and recorded nine duck species breeding at the pan (Table C.1): Cape Shoveler, Cape Teal and Egyptian Goose were the most numerous in terms of duckling broods produced. The peak abundance of waterfowl at the pan corresponds to the time when breeding birds would be nesting and raising broods. The islands that form in the dam during inundation plus the vegetated margins of the pan provide safe breeding sites for waterfowl and coupled with increased food abundance during this period makes Rocher Pan an ideal locality for waterfowl to breed. There are no fish in the pan or lower reaches of the Papkuils River (R van der Walt *in litt.*) mainly due to the pan drying out in most years (du Preez 1992); there are however fish (*Galaxias* and *Sandelia* spp.) in the middle and upper reaches of the river (L Jacobs in litt.). The pan does support fairly high numbers of frogs (mainly *Platanna*) (du Preez 1992) and waterfowl and other species will make use of this food resource when it becomes available (AJ Williams *in litt.*). Without competition from fish there is more amphibian food (tadpoles and froglets) for the ducklings and the pan is safer for adult waterfowl to raise their broods. When considering the surrounding arid landscape, most of it comprises cultivated farmland, with limited natural vegetation and a few small natural wetlands linked to the Papkuils and Sout drainage systems. Consequently, Rocher Pan is the only large, viable wetland that can support relatively large numbers of waterbirds for any length of time during the year and why many waterfowl breed at the pan during periods of inundation. As such it plays a crucial ecological role for a suite of species within a defined region of the winter rainfall region (Zaloumis and Milstein 1975). One of the main reasons for proclaiming the nature reserve was to establish and conserve the pan as a waterfowl breeding sanctuary, particularly for Cape Shoveler, and based on the results from this study it is strongly recommended that this continues.

Other species that are known to breed at the pan include African Sacred Ibis, and small numbers of Kelp Gull which breed on the islands; White-breasted Cormorants also collect nesting material from the pan and transfer it to their nesting colony in isolated trees 500 m south of the pan (AJ Williams in litt.).

One also needs to consider the impacts of predation which at relatively natural wetlands such as Rocher Pan may be more pronounced than it is in permanent intra-urban wetlands such as Strandfontein Waste Water Treatment Works and Paarl Waste Water Treatment Works. Located within a nature reserve a range of potential predators exists for waterbirds, including African Fish Eagle, African Marsh Harrier and Pied Crows among birds, and probably Caracal *Felis caracal*, African Wild Cat *Felis silvestris*, and mongoose and even jackal among medium sized mammals. However, with the exception of the bird predators, mammalian predators are strongly geared to the terrestrial habitats and prey in the reserve and are likely to avoid the waterbody and its wetter peripheries (where the ducks mostly breed). Fortunately, because of its ephemerality, and distance from other permanent freshwater there are unlikely to be Water Mongoose *Atilax paludinosus*. Identification of nest predators and their impact on breeding success of waterfowl forms part of the nature reserve's management plan (du Preez 1992) but it is unknown if this is carried out regularly. If not, it would be strongly recommended for reserve staff to prioritise this activity in future.

Use by seabirds and other coastal birds

The close proximity of Rocher Pan to the coast (< 500 m) allows seabirds and other coastal species to access the pan easily. Sandwich and Common Terns were not abundant at Rocher Pan and these species probably used the pan as a roosting and bathing site. There is likely to be some tidal and weather influences on the use of the pan by seabirds. When the tide is high or bad weather pushes waves high up the beach, birds which might normally roost and/or forage along the beach will move onto the pan as a better and safer alternative.

In contrast, White-winged Terns were the most abundant migrant tern. Their occurrence at the pan would relate to benefiting from the expected abundant food supply in the system in early spring and summer when aquatic chironomid and other aquatic larvae would be pupating and emerging from the water column (Appendix A). High macronutrient influx occurs soon after inundation in May/June with subsequent increases in the following months of zooplankton communities, notably Cladocerans (*Daphnia* spp.) (Coetzer 1985); the latter would form a large proportion of the aquatic chironomid larvae's diet before pupating.

Of the resident terns, the Swift Tern was the only abundant species but like the Palearctic terns, possibly only used the site as a roosting refuge. Their numbers peaked during winter, a few months prior to the influx of Palearctic terns, but did occur in small numbers during the rest of the year. Their occurrence probably relates to post-breeding dispersal of adults and juveniles from their breeding sites which were occupied during February–March; 80% of the South African breeding population breeds at islands between Cape Town and Saldanha Bay (Crawford 1997), the latter about 80 km south of Rocher Pan. Caspian Terns were most frequently present in August with smaller numbers throughout the year. Their occurrence, like the Swift Terns, probably relates to post-breeding dispersal and in the absence of fish in the pan makes use of the islands in the pan for roosting rather than feeding in the pan.

African Black Oystercatchers are generally found in coastal rocky habitats, but they do occasionally use wetlands near the coast (Martin 1997, pers obs.). Most birds were recorded at Rocher Pan from June–September (with some birds at other times of the year).

A small population breeds on the adjacent stretch of sandy beach and it is likely that these birds use the pan for bathing and as a safe roosting place (AJ Williams *in litt.*). It is probable that small influxes occur from dispersing juveniles most of which would have fledged between January and April (Hockey 1983).

Bio-impacts of waterbirds on the pan ecosystem

With the large numbers of waterfowl and other waterbirds that use Rocher Pan, one needs to consider their direct impacts on the ecosystem. Williams (2003) suggested that nutrient turnover is an important aspect in wetland ecosystems especially where waterbirds feature as the main faunal component. Initially as the pan fills, detritus forms from the deposition of organic material (Coetzer 1981). Zooplankton then feed on the detritus and aquatic invertebrates feed on the zooplankton. Waterbirds make use of the rich aquatic invertebrate community and return nutrients back to the waterbody via their faeces. This increasingly enriches the water as it dries down. Seabirds and waterfowl such as Egyptian Goose forage away from the pan but drop faeces there whilst roosting so there is a net input of nutrients to the system. How important such inputs are to the vegetation has not been established but may be substantial.

Impacts can be taken to the broader landscape level. As an ephemeral system, plant use is curtailed in Rocher Pan by the changing conditions which preclude most of the upland (terrestrial) plants of the area and lead to dominance by specialist azonal wetland plant species (e.g. *Potamogeton* spp). To spread between disparate and generally well separated waterbodies, especially in this part of the winter rainfall region, these plants produce large amounts of seed. This provides food for waterbirds, especially dabbling ducks (Yellow-billed Duck, Cape Teal, Red-billed Teal) and the ducks transport viable seeds between wetlands.

Conservation importance

Waterbird Conservation Value (WCV) scores

In assessing the importance of Rocher Pan for waterbirds in the winter-rainfall region and the arid west coast of the Western Cape further discussion on the WCV score is needed. The fundamental value of the score lies in its ability to assess each species' contribution to the overall conservation importance of the site, independent of other variables such as energy consumption. This means that while a species may not reach global population threshold levels it contributes to the overall conservation value of the site when seen at the community level. Thus, populations of species at a site which have higher cumulative 1% scores would signify that site of higher conservation value than a site which has lower scores. The WCV score thus reflects the usage of a site in terms of the number of birds present, such that the more individuals using it per species the greater the value it represents to them. For Rocher Pan, 20 of the 64 species surveyed revealed that the site held importance for their populations both at a global and sub-regional scale (Table C.2). Their use of the site, however, varied across years although general patterns were evident: specific species tended to peak at the same time of year (e.g. Black-necked Grebe and Black-winged Stilt in September/October, White-breasted Cormorant in December/January and Pied Avocet in December/February). These inter-annual WCVS fluctuations, coupled with rainfall and *in situ* site characteristics, will then influence when the site is of prime importance for the waterbird community as a whole and for individual species. It is interesting to note that while some species meet globally or biogeographically significant thresholds, others meet more local thresholds; seventeen species (Table C.2) at Rocher Pan comprised population levels that strongly suggest they make valuable contributions to the species population in the province. This then infers that they make up an important component of waterbird populations in the winter-rainfall region.

Importance of waterfowl at Rocher Pan

As mentioned above, waterfowl constitute an important component of the waterbird community at Rocher Pan and nine species occurred at important threshold levels during this study. For Cape Shoveler, the site's original icon species, the data did show that the site was used regularly by a significant part of the southern African population and that the site therefore continued to be favoured by this species. The suitable water-levels and availability of aquatic invertebrates following inundation no doubt are strong selection factors for the shoveler in using Rocher Pan. No other wetland sites along the west coast support numbers of Cape Shoveler at the levels recorded at Rocher Pan (Coordinated Waterbird Counts, Animal Demography Unit, unpubl. data), highlighting the importance of this site for the species in South Africa. The site becomes of even greater international importance for the species when it is considered that it is endemic to southern Africa (Siegfried 1965, Hockey et al. 2005). Other waterfowl, Yellow-billed Duck and Great Crested Grebe, did occur at globally significant levels but these levels were not maintained on a regular basis suggesting that they only use Rocher Pan when other sites become sub-optimal or when there is an abundance of suitable foraging prey. This suggests that birds may 'monitor' the conditions at Rocher Pan and make seasonal use of a short-term foraging resource.

At a sub-regional level (Barnes 1998), populations of Red-knobbed Coot, Cape Teal, South African Shelduck and Maccoa Duck are important at Rocher Pan but with only single counts at these levels (see Table 2) it does suggest they make use of other wetland sites in the region on a more regular basis. Fulvous Duck, Southern Pochard and White-backed Duck are rare ducks in the Western Cape with low populations (Hockey et al. 1989) but do occur in fairly good numbers at Rocher Pan making the site of conservation importance to these species.

For other waterbirds, the site held importance for resident shorebirds (Pied Avocet, Black-winged Stilt, Greater Flamingo and Lesser Flamingo). As the pan begins to dry out from October, water-levels drop making it attractive for these species to use it for foraging. Black-winged Stilts were regular visitors to Rocher Pan, while Pied Avocet, and Greater and Lesser Flamingo, less so, and suggests that the stilts use Rocher Pan as preferred site while the avocets and flamingos use other regional wetlands before arriving at the pan. This is probably related to inundation levels at the pan and other surrounding wetlands from year to year.

Whether waterbirds use Rocher Pan regularly or not, the availability of suitable wetlands, at all stages in their annual cycle, is critical to the long-term survival of their populations in the region. Consequently, conservation authorities in the province have a responsibility to ensure that conservation targets are reached for these species, including the provision of suitable sites. Based on this, it is therefore strongly recommended that the current conservation status of the site (i.e. provincial nature reserve), continues in the long-term in order to safe-guard it as a sanctuary for the Cape Shoveler, and other waterfowl (Siegfried 1970).

The site qualifies for Ramsar and Important Bird Area (IBA) status based on the species listed in Table 2. These global conservation initiatives aim to prioritise important global and regional wetland and bird conservation sites for biodiversity conservation (Barnes 1998, Fishpool and Evans 2001). The designation of Rocher Pan as a Ramsar and/or IBA site will greatly enhance the conservation status of the site and secure the long-term preservation of this wetland for waterbirds in the winter-rainfall region.

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Table C.1 Summary of waterbird counts for Rocher Pan from 1979–2004. Species in bold were counted from 1979–2004 (N=273, n=141 summer, n=132 winter); those not in bold from 1985–2004 (N=201; n=105 summer, n=96 winter) (see text for details). Species marked with an asterisk (*) were recorded on fewer than 25% of surveys. B = duck species recorded breeding (see Heÿl 1985). Species sorted in descending order of mean summer abundance.

Species	Summer		Winter	
	Mean	Min-Max[1]	Mean	Min-Max[1]
Residents				
Waterfowl				
Red-knobbed Coot	716.8 ± 710.2	0–6259	477.1 ± 505.8	230–3130
Cape Shoveler	300.5 ± 231.3	0–1619	155.7 ± 152	46–1090
Cape Teal	85.7 ± 87.6	0–1069	29.7 ± 44.4	0–595
Red-billed Teal	61.1 ± 53.4	0–836	14.3 ± 19.2	0–447
Yellow-billed Duck	49.1 ± 38.2	0–1113	29 ± 21.6	13–103
Egyptian Goose	38.6 ± 39.1	0–660	17.5 ± 15.5	0–323
South African Shelduck	32.5 ± 18.2	0–285	12 ± 6.6	0–219
Black-necked Grebe	28.8 ± 48.4	0–650	61.1 ± 75.8	0–661
Little Grebe	14.7 ± 14.7	0–298	22.8 ± 24.3	0–250
Moorhen	4.1 ± 4.7	0–47	3.1 ± 4.7	0–40
Maccoa Duck	4.1 ± 5.1	0–45	5 ± 5.8	0–49
Southern Pochard	2.2 ± 2.8	0–47	2.1 ± 2.8	0–79
Great Crested Grebe*	1.4 ± 1.3	0–25	1.8 ± 2.5	0–102
Spur-winged Goose*	1.1 ± 0.9	0–21	0.5 ± 0.5	0–11
White-backed Duck*	0.4 ± 0.8	0–38	0.1 ± 0.2	0–4
Fulvous Duck*	0.2 ± 0.3	0–15	0 ± 0	0–0
Hottentot Teal*	0.1 ± 0.2	0–3	0 ± 0	0–0
White-faced Duck*	0.1 ± 0.1	0–1	0 ± 0	0–0
Sub-total	**1340.6 ± 1256.3**	**0–13031**	**831.1 ± 880.9**	**289–7103**
Cormorants and darter				
White-breasted Cormorant	142 ± 99.3	0–772	58.5 ± 37.1	0–490
Reed Cormorant	4.8 ± 4.3	0–73	0.8 ± 1.5	0–21
Cape Cormorant*	0.1 ± 0.2	0–2	0.1 ± 0.1	0–1
Bank Cormorant*	0.1 ± 0.1	0–2	0 ± 0	0–0
African Darter*	0.1 ± 0.1	0–2	0.1 ± 0.1	0–3
Sub-total	**146.9 ± 103.8**	**0–851**	**59.3 ± 38.6**	**0–515**
Pelicans				
Great White Pelican*	**4.1 ± 3.2**	**0–114**	**0.4 ± 0.4**	**0–14**
Flamingos				
Greater Flamingo	395.5 ± 375.7	0–4239	225.5 ± 333.4	0–2467
Lesser Flamingo	60.5 ± 32.4	0–1082	13.6 ± 15.2	0–528
Sub-total	**456 ± 408.1**	**0–5321**	**239.1 ± 348.6**	**0–2995**
Waders				
African Sacred Ibis	44.5 ± 49	0–468	37.1 ± 55.3	0–578
Glossy ibis	17.3 ± 14.2	0–130	0.4 ± 0.6	0–10
African Spoonbill	4.4 ± 2.9	0–33	0.6 ± 0.8	0–12
Grey Heron	2.3 ± 1.5	0–16	0.3 ± 0.4	0–4
Black-crowned Night-heron*	1.3 ± 1.3	0–29	0.2 ± 0.3	0–5
Little Egret*	1 ± 0.9	0–17	0.1 ± 0.1	0–3
Cattle Egret*	0.9 ± 1.5	0–41	3.3 ± 6.5	0–144
Black-headed Heron	0.7 ± 0.5	0–9	0.6 ± 0.5	0–4
Purple Heron*	0.3 ± 0.3	0–3	0.2 ± 0.3	0–1
Yellow-billed Egret*	0.2 ± 0.2	0–5	0.1 ± 0.1	0–1
Great White Egret*	0.1 ± 0.1	0–2	0 ± 0	0–0
Black Stork*	0.1 ± 0.1	0–2	0 ± 0	0–0
Sub-total	**72.4 ± 72**	**0–755**	**42.4 ± 64.4**	**0–762**

Table C.1 contd

Species	Summer		Winter	
	Mean	Min-Max[1]	Mean	Min-Max[1]
Shorebirds				
Blackwinged Stilt	113.6 ± 139.8	0–868	58.3 ± 85.5	0–497
Kittlitz's Plover	60.6 ± 43	0–368	25.6 ± 5.4	0–208
Pied Avocet	37.7 ± 23.2	0–715	1.1 ± 1.2	0–43
Blacksmith Lapwing	21.5 ± 13	0–147	13.3 ± 9.1	0–75
African Black Oystercatcher	4.3 ± 3.2	0–27	10.4 ± 4.7	0–33
Three–banded Plover	2.9 ± 1.2	0–37	2.3 ± 3.5	0–121
Whitefronted Plover*	2.4 ± 1.6	0–80	1.1 ± 1	0–17
African Snipe*	0.3 ± 0.5	0–22	0 ± 0	0–0
Chestnut–banded Plover*	0.2 ± 0.3	0–5	0.1 ± 0.1	0–3
Painted Snipe*	0.1 ± 0.1	0–2	0.1 ± 0.1	0–1
Sub–total	**243.2 ± 225.6**	**0–2271**	**111.9 ± 110.2**	**0–998**
Raptors				
African Marsh Harrier*	0.2 ± 0.2	0–2	0.1 ± 0.2	0–2
African Fish Eagle*	0 ± 0	0–0	0.1 ± 0.1	0–1
Sub–total	**0.2 ± 0.2**	**0–2**	**0.1 ± 0.1**	**0–2**
Rallids				
Purple Gallinule*	0.1 ± 0.1	0–2	0.1 ± 0.1	–
African Rail*	0.1 ± 0.1	0–2	0.1 ± 0.1	0–2
Black Crake*	0.1 ± 0.1	0–2	0 ± 0	0–2
African Jacana*	0 ± 0	0–0	0 ± 0	0–0
Sub–total	**0.2 ± 0.2**	**0–4**	**0.1 ± 0.1**	**0–1**
Gulls				
Kelp Gull	67.9 ± 39.4	0–953	50.6 ± 33.5	0–391
Hartlaub's Gull	45.6 ± 41.1	0–305	83.5 ± 56.7	0–571
Greyheaded Gull*	0.3 ± 0.3	0–10	0.4 ± 0.3	0–7
Sub–total	**113.7 ± 80.7**	**0–1268**	**134.5 ± 90.4**	**0–969**
Terns	0 ± 0		0 ± 0	
Whiskered Tern*	0.8 ± 1.2	0–44	0.1 ± 0.1	0–1
Swift Tern	3.7 ± 4.6	0–108	29.9 ± 30.8	0–435
Caspian Tern*	0.7 ± 0.6	0–17	2.5 ± 4.3	0–180
Sub–total	**5.1 ± 6.2**	**0–169**	**32.3 ± 35**	**0–616**
Palearctic migrants				
Shorebirds				
Curlew Sandpiper	480 ± 372.8	0–5012	16.4 ± 23.5	0–409
Little Stint	176.1 ± 79.7	0–1243	6.9 ± 9.5	0–124
Ruff	78.4 ± 49.2	0–600	16 ± 35.7	0–247
Marsh Sandpiper	19.1 ± 16.3	0–276	0.5 ± 0.8	0–17
Common Greenshank	3.4 ± 2.5	0–52	0.3 ± 0.3	0–9
Common Ringed Plover	3 ± 1.8	0–32	0.3 ± 0.5	0–7
Wood Sandpiper*	0.8 ± 0.4	0–6	0.1 ± 0.1	0–4
Sanderling*	0.5 ± 1.2	0–49	0 ± 0	0–0
Common Sandpiper*	0.2 ± 0.4	0–6	0.1 ± 0.1	0–2
Ruddy Turnstone*	0.2 ± 0.3	0–7	0.1 ± 0.1	0–1
Grey Plover*	0.1 ± 0.1	0–5	0 ± 0	0–0
Bartailed Godwit*	0.1 ± 0.1	0–4	0 ± 0	0–0
Common Whimbrel*	0.1 ± 0.1	0–3	0 ± 0	0–0
Eurasian Curlew*	0.1 ± 0.1	0–3	0.1 ± 0.1	0–2
Terek Sandpiper*	0.1 ± 0.1	0–1	0.1 ± 0.1	0–1
Sub–total	**716.8 ± 710.2**	**0–7299**	**477.1 ± 505.8**	**0–823**

Table C.1 contd

Species	Summer		Winter	
	Mean	Min–Max[1]	Mean	Min–Max[1]
Terns				
Whitewinged Tern	47.8 ± 43.2	0–683	37.1 ± 71.9	0–1662
Common Tern*	5.9 ± 7.3	0–163	2.9 ± 2.9	0–95
Sandwich Tern*	0.2 ± 0.2	0–8	0.6 ± 0.6	0–24
Sub–total	53.7 ± 50.7	0–854	40.5 ± 75.3	0–1781
Sub–total: residents	2381.9 ± 2155.9	0–18521	1450.6 ± 1568.5	289–13978
Sub–total: Palearctic migrants	815.2 ± 575.1	0–7109	80.7 ± 145.5	0–2654
Total waterbirds	3197.1 ± 2731.0	0–13708	1531.3 ± 1714.0	289–8498

[1] The sub-total values here reflect the minimum/ maximum number for the group profile as a whole and not the sum of individual minima/maxima for each species which would represent estimated min./max. carrying capaicty and not actual min./max. numbers reflected by the dataset

Table C.2. Species of conservation importance at Rocher Pan based on maximum counts from 201 surveys from June 1979 to July 2004. Species are sorted in descending order of global, sub-regional IBA and provincial. Species in bold are included in the South African Red Data book (Barnes 2000); NT = Near-threatened. Species names are taken from Hockey et al. (2005).

Species	Max. count	Threshold/population level		
		Global[1]	IBA[2]	Western Cape[3]
Caspian Tern	180	12% (3)	3	32%
White-breasted Cormorant	772	6.43% (57)	48	15%
Greater Flamingo (NT)	4231	5.58% (44)	35	21%
Cape Shoveler	1619	4.63% (67)	58	19%
Black-necked Grebe	661	4.41% (17)	17	20%
Black-winged Stilt	868	3.77% (29)	22	17%
Pied Avocet	715	2.50% (5)	7	14.%
Swift Tern	435	2.18% (4)	4	7%
Hartlaub's Gull	571	1.90% (5)	22	7%
Lesser Flamingo (NT)	1082	1.80% (2)	11	16%
Curlew Sandpiper	5012	1.52% (3)	3	9%
Kelp Gull	953	1.36% (1)	7	7%
Yellow-billed Duck	1113	1.10% (1)	1	7%
Great Crested Grebe	102	1.02% (1)	–	7%
African Black Oystercatcher (NT)	33	–	8	5%
Red-knobbed Coot	6259	–	1	8%
Cape Teal	1069	–	1	2%
Great White Pelican (NT)	114	–	1	3%
South African Shelduck	285	–	1	2%
Maccoa Duck	49	–	1	5%
White-winged Tern	1662	–	–	48%
Fulvous Duck	15	–	–	47%
Red-billed Teal	836	–	–	32%
Marsh Sandpiper	276	–	–	20%
African Snipe	22	–	–	15%
Glossy Ibis	130	–	–	13%
African Sacred Ibis`	578	–	–	13%
Black-crowned Night-heron	29	–	–	10%
Ruff	600	–	–	9%
Little Stint	1243	–	–	9%
Three-banded Plover	121	–	–	7%
Kittlitz's Plover	368	–	–	7%
Little Grebe	298	–	–	6%
White-backed Duck	38	–	–	5%
Whiskered Tern	44	–	–	5%
Southern Pochard	79	–	–	5%
White-fronted Plover	80	–	–	5%

[1] Calculated from Wetlands International (2006). Figures represent the percentage of the estimated global population based on the maximum count. Number in parentheses represents the number of counts which met or surpassed the 1% threshold level.
[2] Figures represent the number of counts which met or surpassed the Sub-regional IBA level (0.5% threshold) for southern Africa (Barnes 1998) but did not surpass the 1% global threshold level.
[3] Value represents the % of estimated provincial population and based on the maximum count. Sourced from Coordinated Waterbird Counts, Avian Demography Unit, unpublished data (2006)

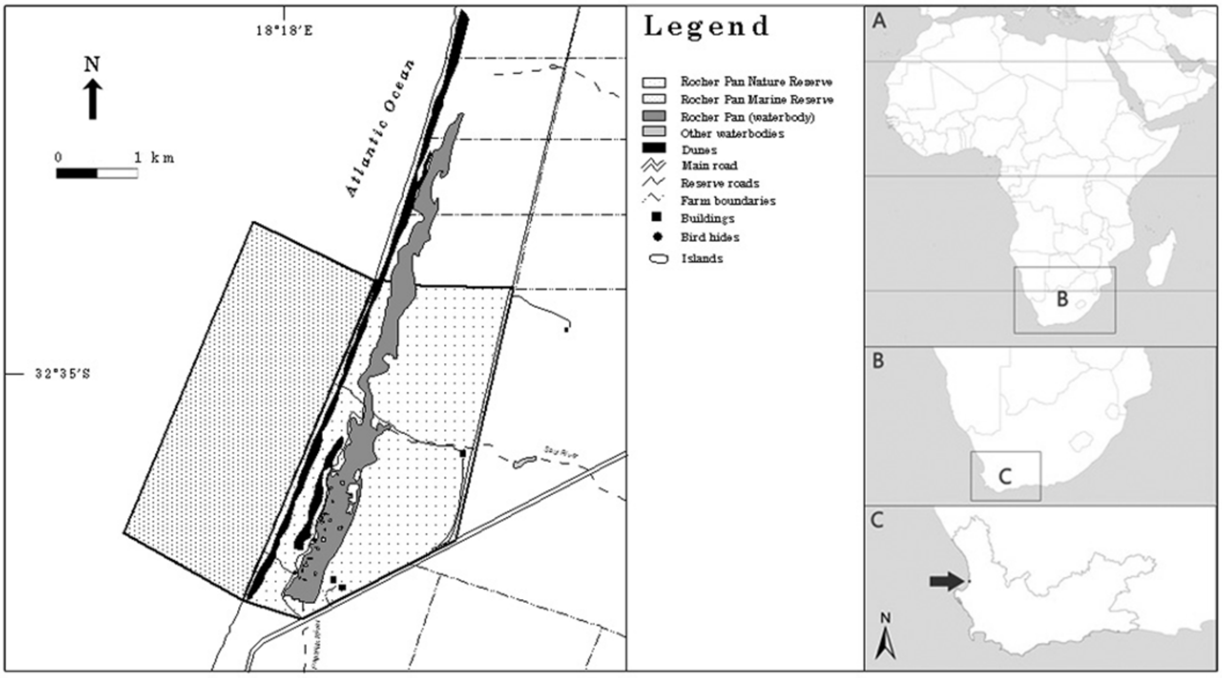


Figure C.1 Rocher Pan Nature Reserve (lightly stippled) and Marine Reserve (intermediate stipple). The Rocher Pan wetland is shaded in grey.

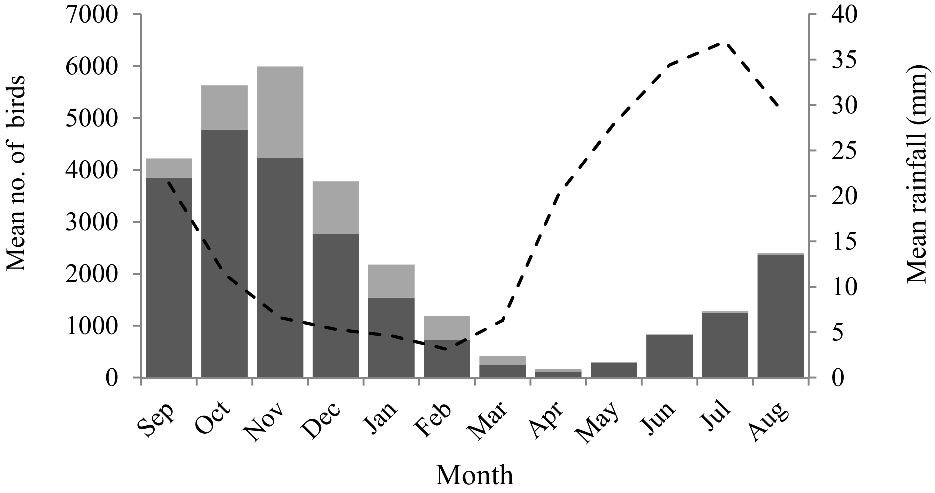


Figure C.2 Mean monthly abundance of all waterbirds at Rocher Pan between 1979–2004. Dark bars = resident species, grey bars = Palearctic species. Mean monthly rainfall is also shown (---) and based on rainfall data from Elandsbaai rainfall station between 1994–2004.

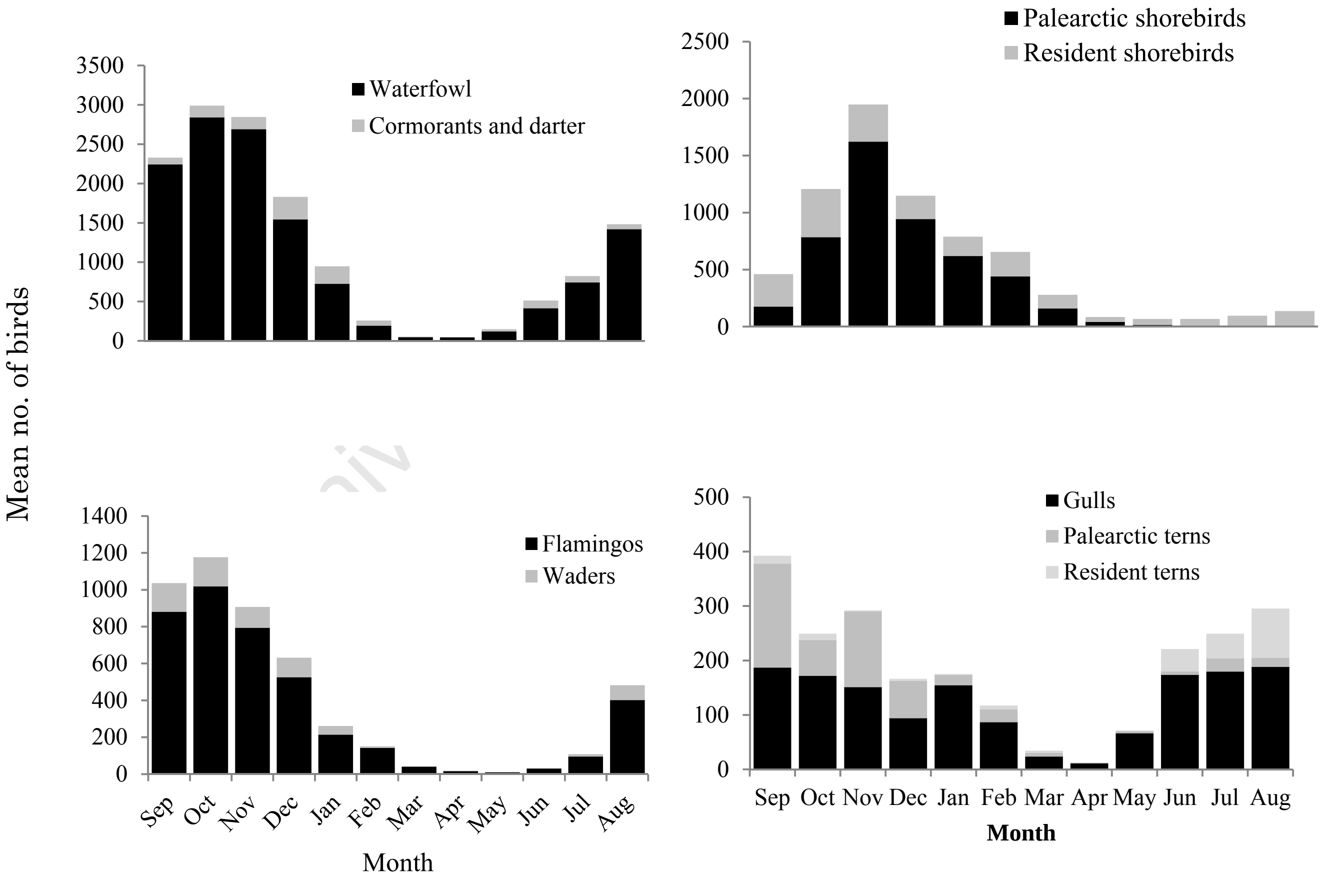


Figure C.3 Mean monthly abundance of nine waterbird guilds at Rocher Pan from 1979–2004.

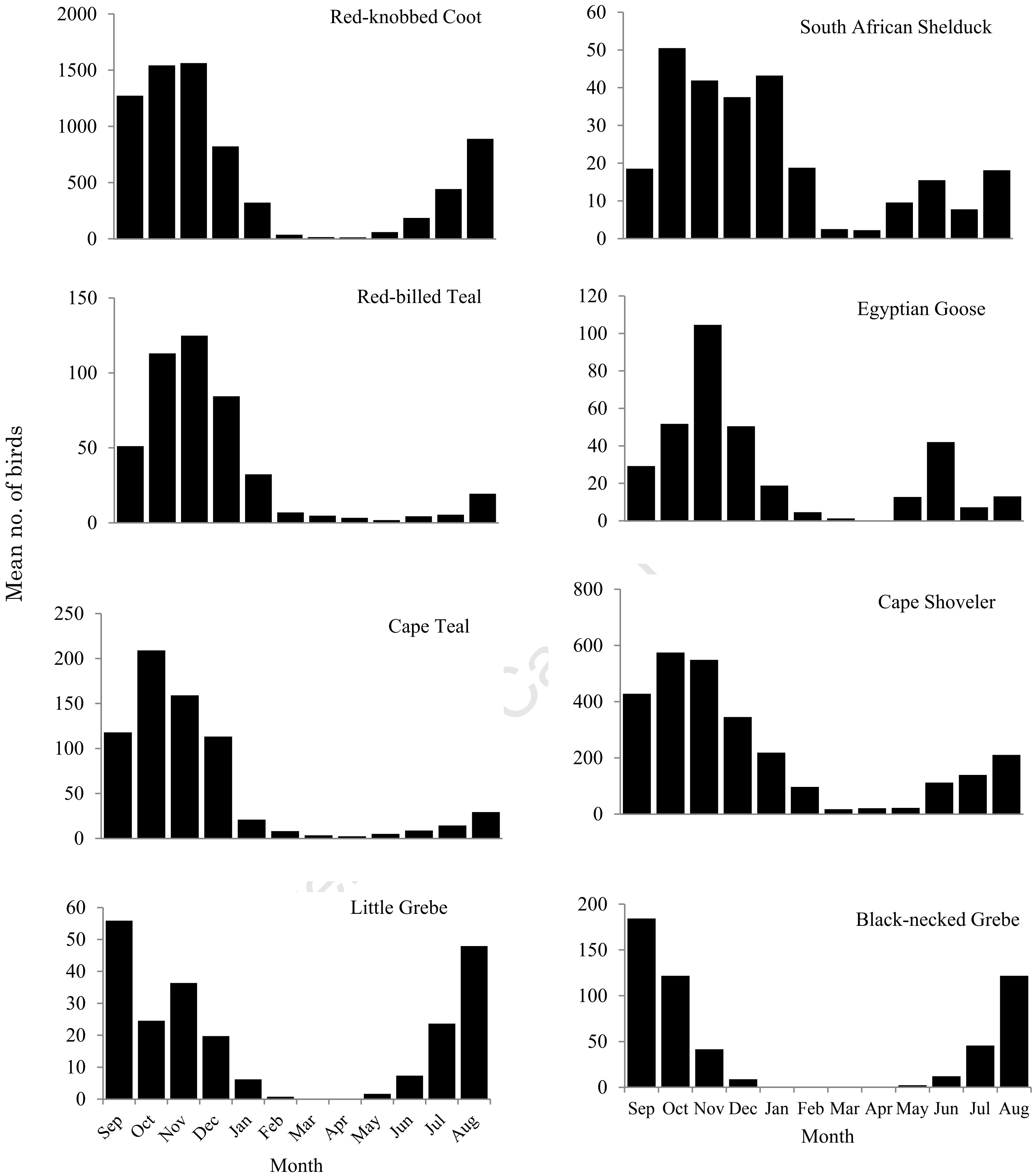


Figure C.4 Mean monthly abundance of eight waterfowl species at Rocher Pan from 1979–2004.

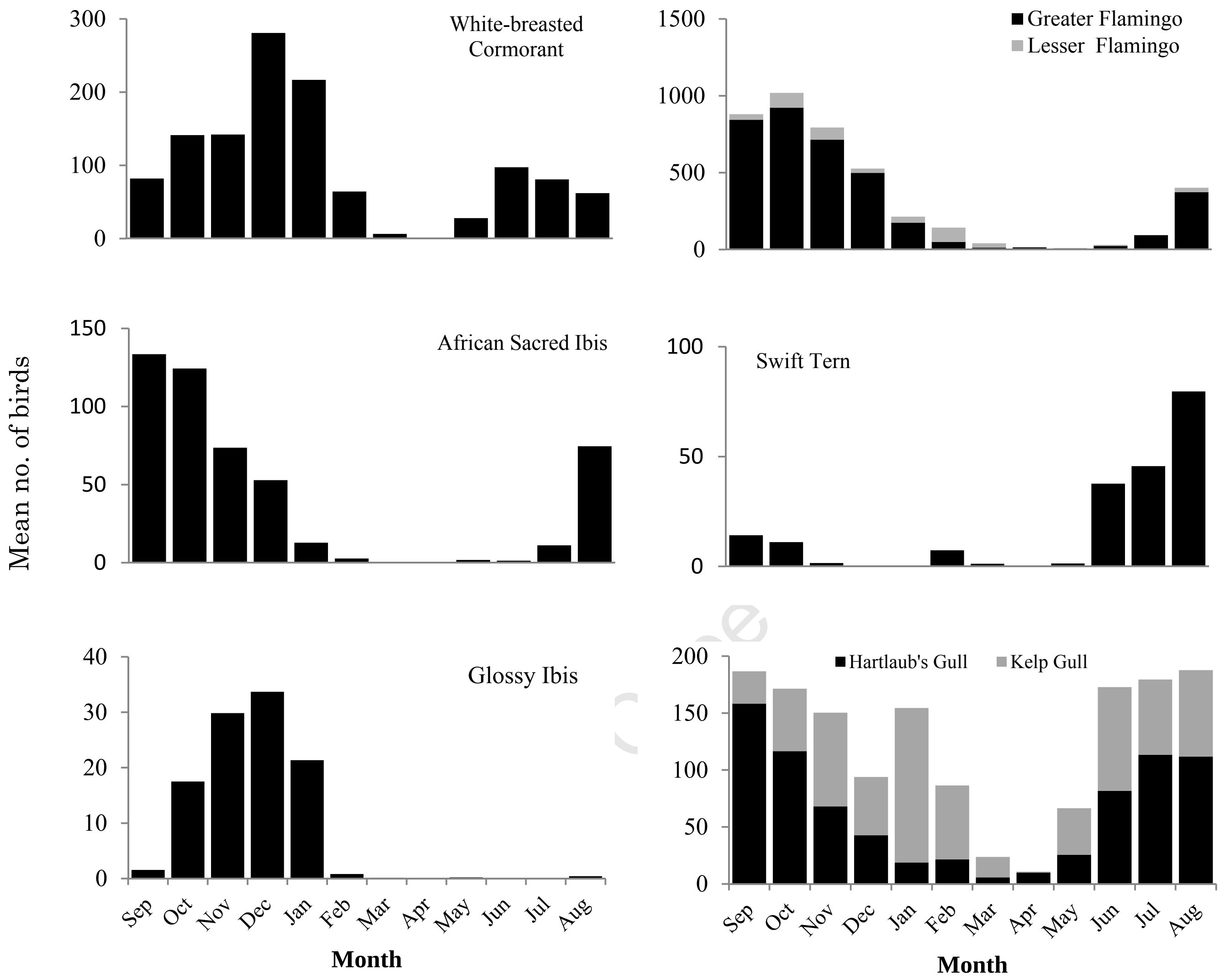


Figure C.5 Mean monthly abundance of eight waterbird species at Rocher Pan from 1979 – 2004.

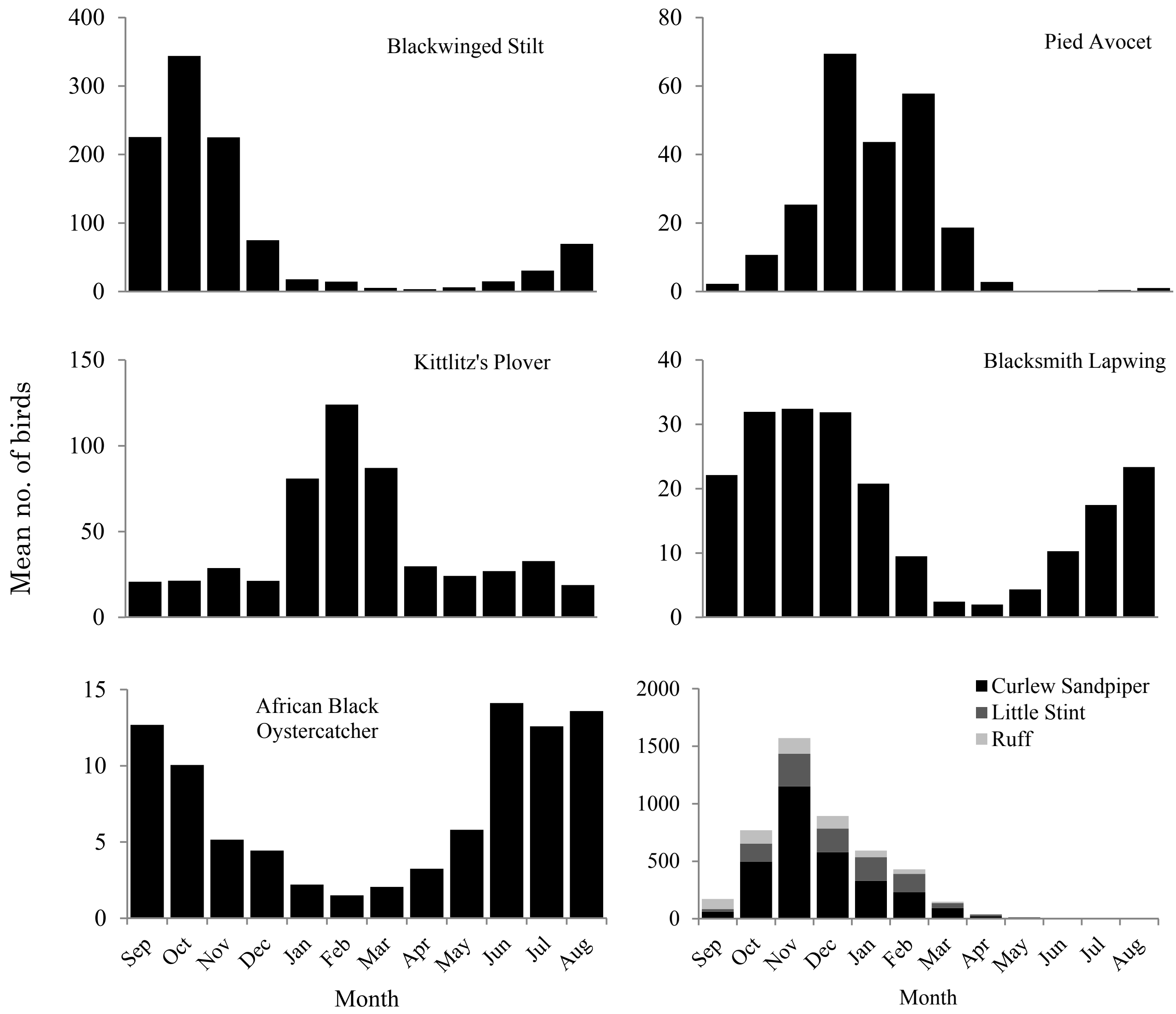


Figure C.6 Mean monthly abundance of selected resident shorebirds and Palearctic shorebirds at Rocher Pan from 1979–2004.

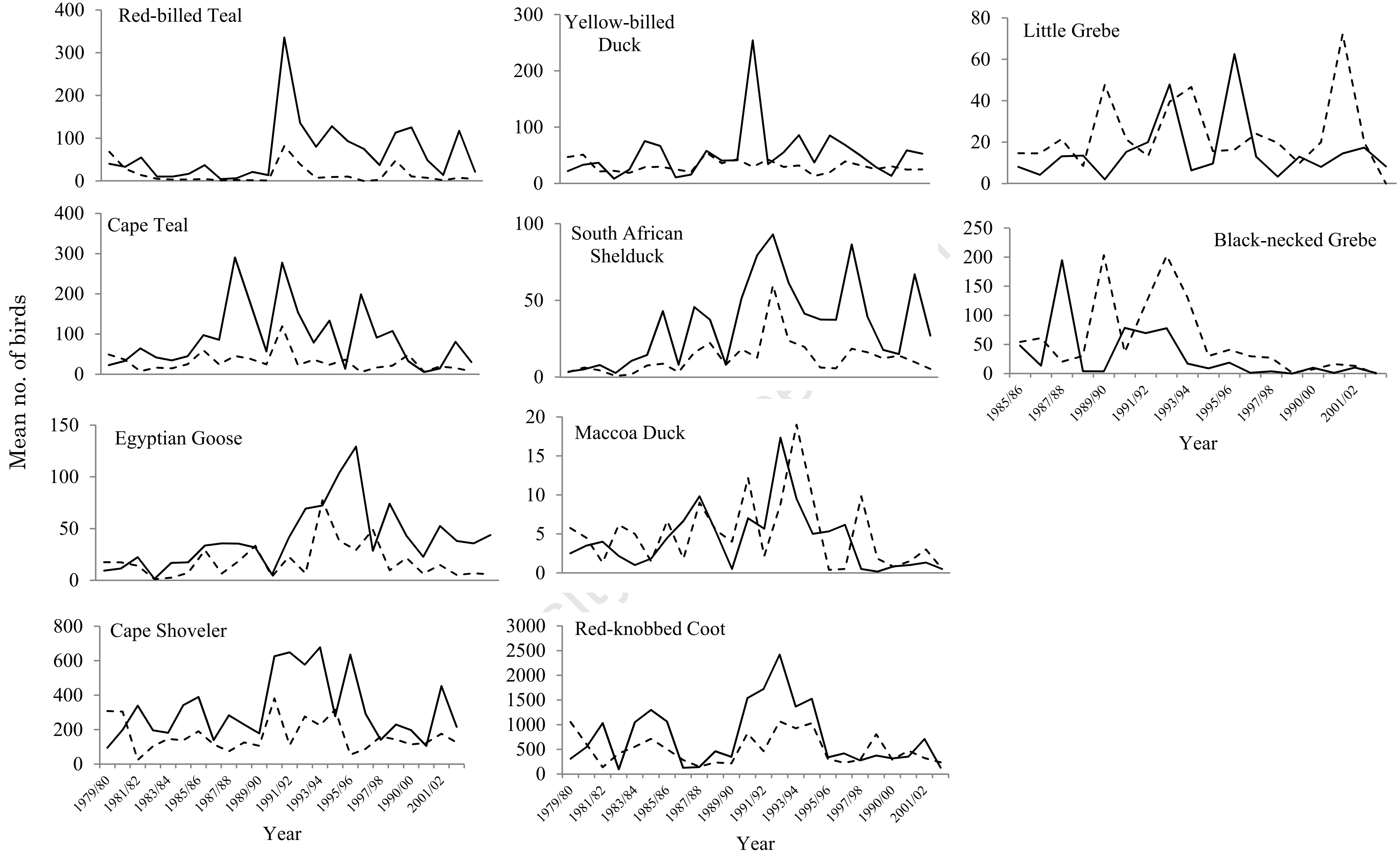


Figure C.7 Summer (solid line) and winter (dashed line) inter-annual variation and trends in abundance of 10 waterfowl species at Rocher Pan from 1979–2004.

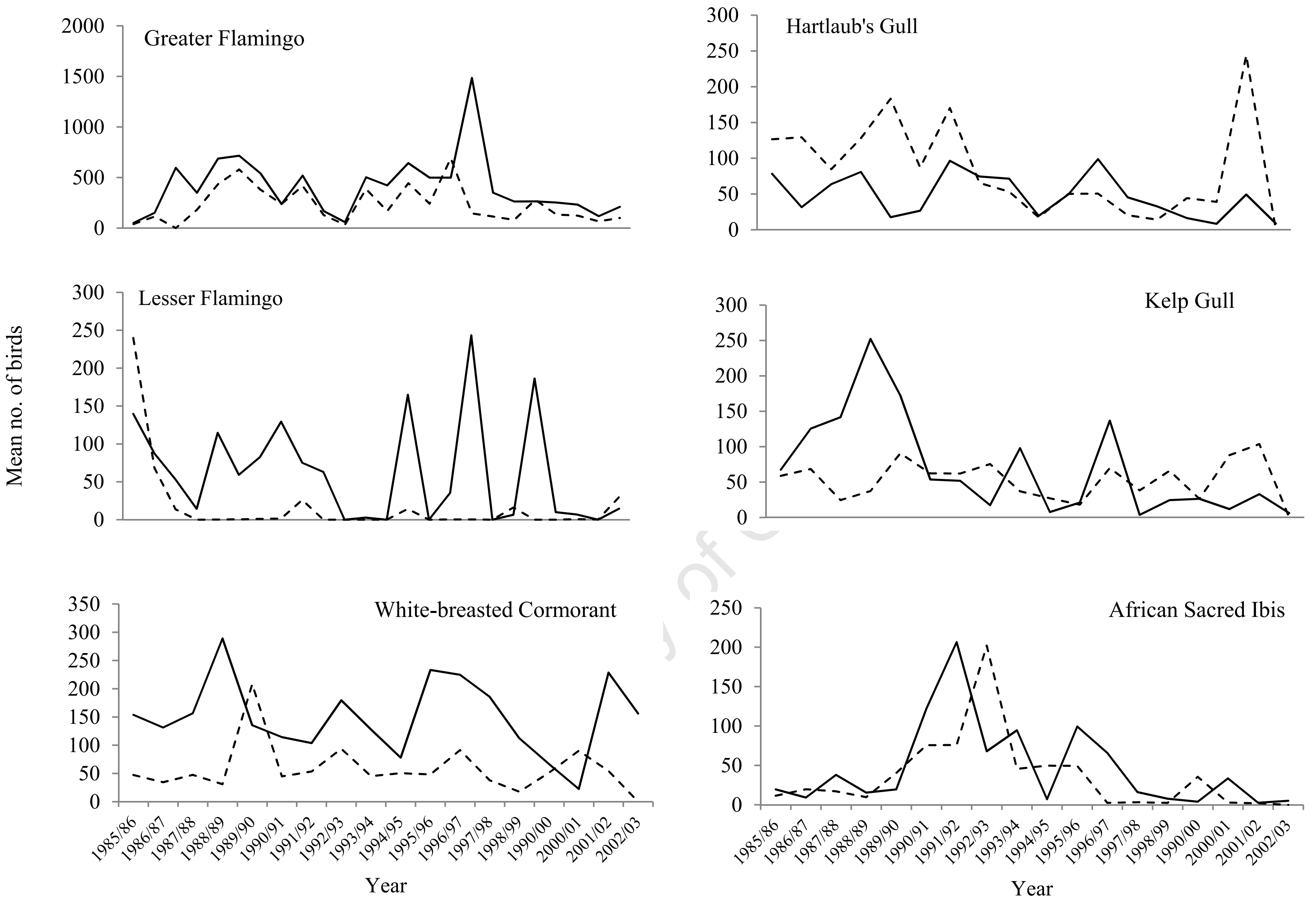


Figure C.8 Inter-annual variation and summer (–) and winter (---) trends in abundance of six waterbird species at Rocher Pan from 1985–2004.

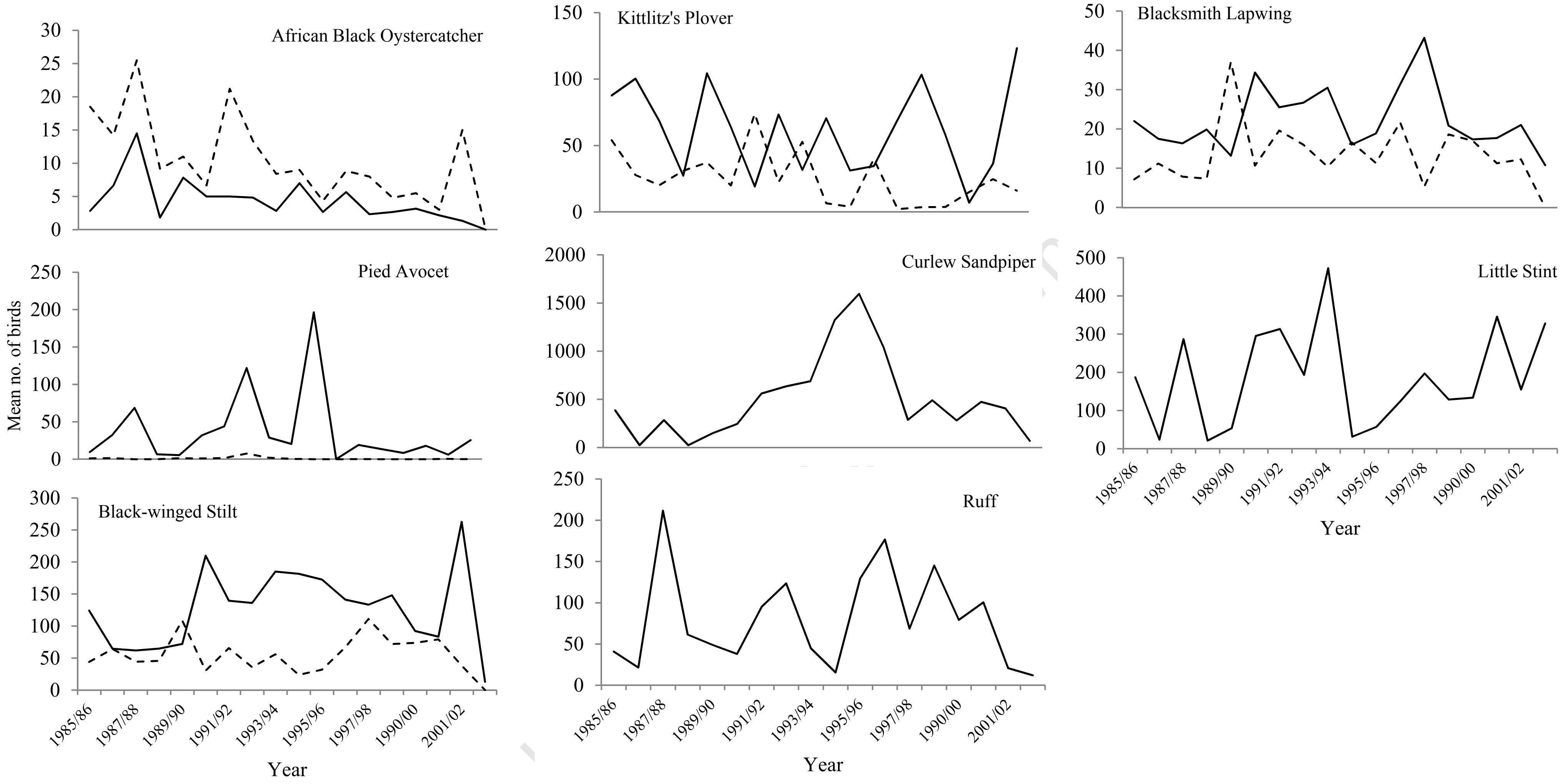


Figure C.9 Inter-annual variation and summer (–) and winter (---) trends in abundance of selected resident and Palearctic shorebirds at Rocher Pan from 1987–2004.

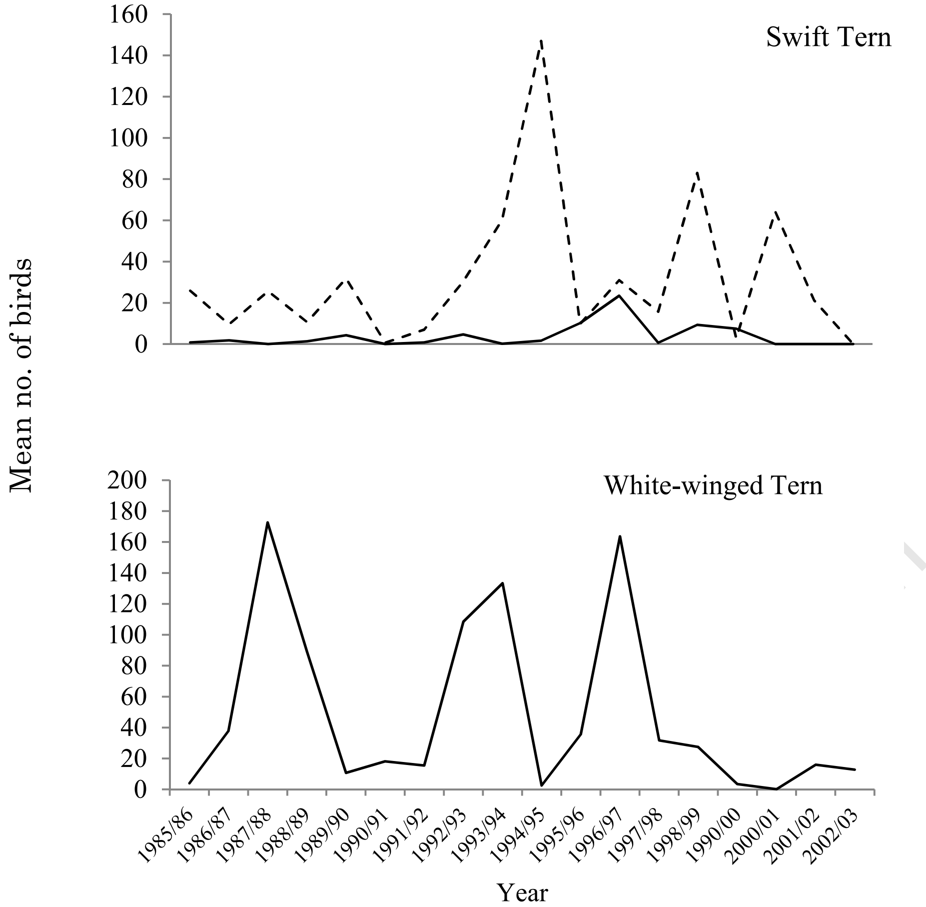


Figure C.10 Inter-annual variation and summer (–) and winter (---) trends in abundance of Swift Tern and White-winged Tern at Rocher Pan from 1987–2004.

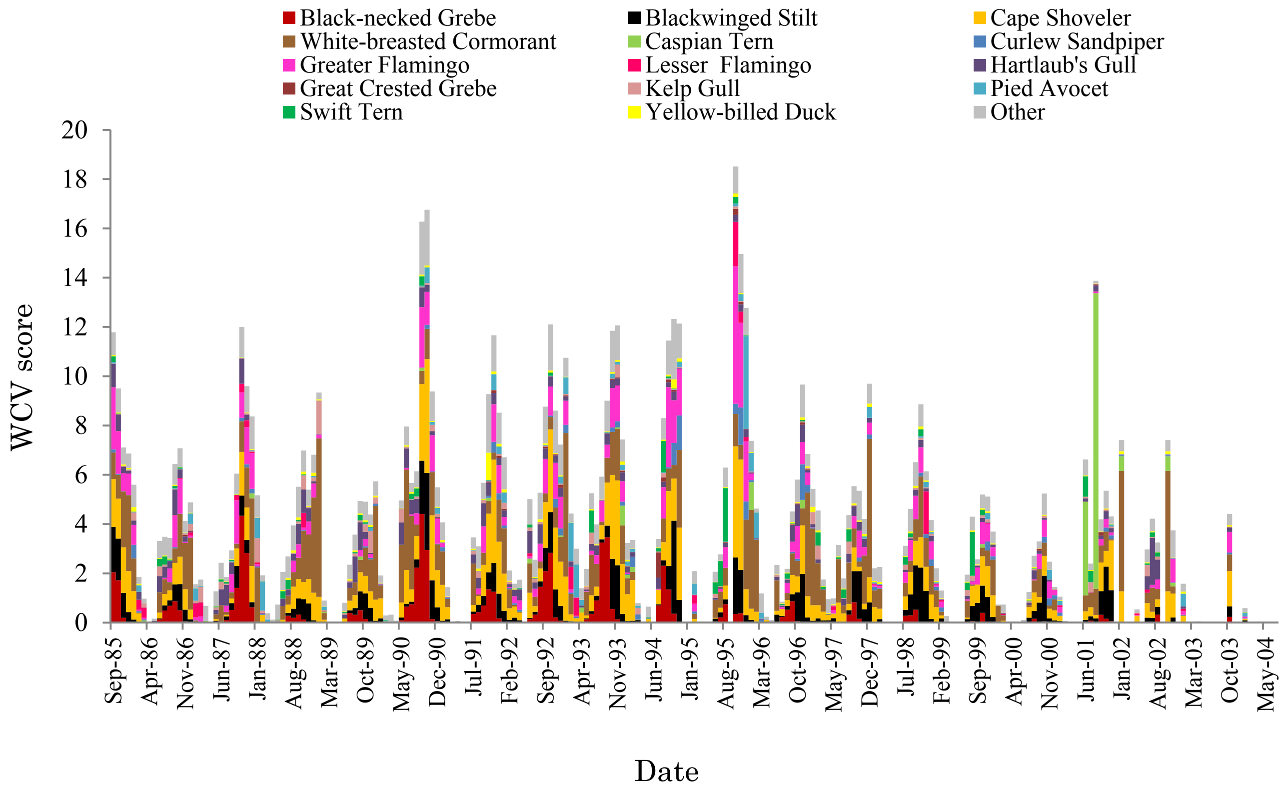
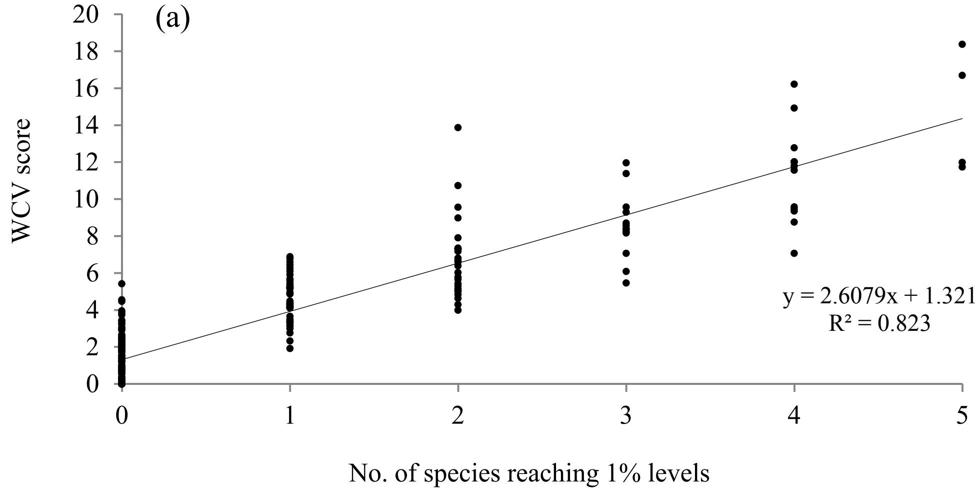


Figure C.11 Monthly Waterbird Conservation Value (WCV) scores for Rocher Pan from September 1985–June 2004. Relative contributions of species reaching 0.5% or 1% threshold levels are shown.



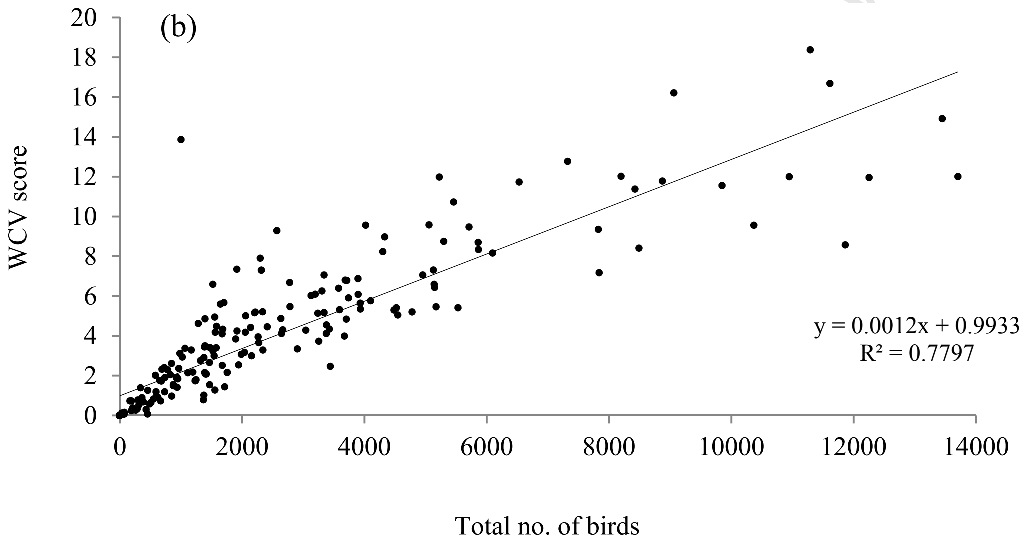
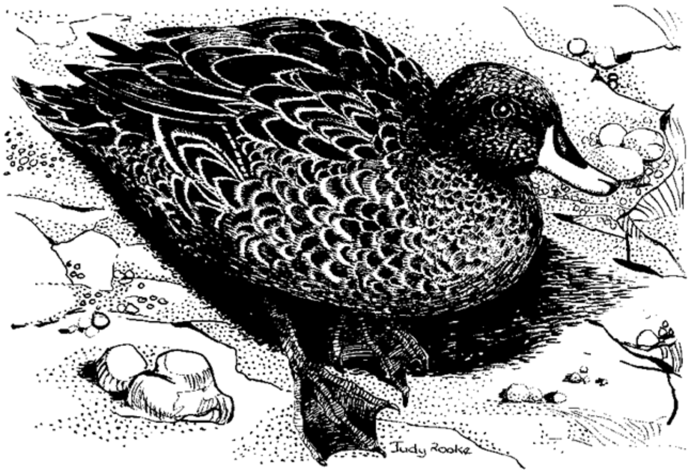


Figure C.12 The relationship between (a) the Waterbird Conservation Value (WCV) score and the number of species reaching their 1% levels and (b) the WCV score and the total count of waterbirds at Rocher Pan . Both plots cover all surveys from September 1985-July 2004 (n = 215).

Appendix D

Waterbirds at De Hoop Vlei, a coastal lake in South Africa, 1979–2009: an assessment of its Ramsar status



Abstract

Waterbird abundance and seasonality was assessed at De Hoop Vlei, a coastal lake located on the Agulhas Plain, South Africa from 1979–2009. A total of 83 waterbird species (65 resident species and 18 migrant species) was recorded and mean abundance was similar in summer (5 710.2 ± 909.6) and winter (5 203.9 ± 534.3). A maximum of 16 338 birds was counted in January 1990. Overall, mean abundance peaked from November–January with a decline in February and a winter peak in May. Small numbers of Palearctic migrants were recorded. Overall mean abundance of waterbirds declined by 43% over the three decade study period (1980s–2000s). Egyptian Goose, Spur-winged Goose, Cape Teal and Great White Pelican showed at least a 40% increase since the 1980s, while Cape Shoveler, Southern Pochard, Red-billed Teal, Maccoa Duck, Red-knobbed Coot, Greater Flamingo and Lesser Flamingo decreased by more than 50% between the 1980s and the 2000s. The wetland supported 16 waterbird species which held globally important numbers of birds and 12 threatened species, the most important being Greater Flamingo, Lesser Flamingo and Great White Pelican. It plays an important ecological role as a dry season and moult refuge for regional waterfowl populations. Changes to the waterbird populations at the lake are discussed in light hydrological changes at the lake and future climate change predictions. The sites Ramsar status is also reviewed and recommendations proposed.

Plate D.1 De Hoop Vlei looking northwards from De Mond. Photo: M Wheeler

Introduction

South Africa has few natural lakes (Hart 1995, Davies and Day 1998). Most are confined to the coastal region and are well represented in the eastern (e.g. Lake St Lucia complex, Lake Sibayi and Kosi Bay complex) and southern (e.g. Wilderness Lakes complex) parts of the country (Allanson 1981). In the south-western region a number of coastal wetlands occur (e.g. Soetendalsvlei, Cape Flats vleis) but they are less extensive than the eastern and southern systems.

De Hoop Vlei is one of a few coastal lakes in the winter rainfall region (WRR) of the Western Cape, South Africa (Chapter 1) (Uys and Macleod 1967, Noble and Hemens 1978). It is located on the eastern portion of the Agulhas Plain, a 153 000 ha area of low-lying, rolling coastal plains (Corberia and Conradie 2010); the area forms the southern most region of the African continent (Figure 1.4, Chapter 1). The other major coastal lake is Verlorenvlei situated on the west coast of the WRR (Figure 1.4, Chapter 1). The Agulhas Plain falls within the larger 300 000 ha Overberg Wheatbelt agricultural district where intensive commercial cereal and crop farming takes place (Barnes 1998). As such, much of the natural landscape in the region has been transformed into wheat pastures and crop fields although a fair amount of natural fynbos vegetation does occur along the coast (Barnes 1998). De Hoop Vlei was one of two registered with the Ramsar Convention as a Wetland of International Importance at the time the convention came into force in 1972 (Cowan 1995, Ramsar 2010).

There are few waterbird population studies for coastal wetlands in the Western Cape (e.g. Summers et al. 1976, Heÿl and Currie 1985, Underhill 1987, Kaletja-Summers et al. 2001a, b) and limited information has been published for De Hoop Vlei. Uys and Macleod (1967) provided the first indications of the status of some waterbirds, while Uys (1983) and Heÿl (1988) summarized the importance of the lake for waterbirds. Although surveys of waterbirds have been undertaken as part of regular monitoring activities since 1979, these data have not been analysed in detail. This chapter provides a full analysis of the occurrence and abundance of waterbirds at the lake, reviews the Ramsar status of the site and provides conservation recommendations.

Study area

De Hoop Vlei (34°31'S, 20°23'E) is situated c. 50 km north-east of Cape Agulhas, the most southerly point of Africa. The lake falls within the 34 000 ha De Hoop Nature Reserve and forms its western boundary. Adjacent to the western shoreline and nature reserve boundary is the Overberg Missile Test Range. This stretches from Waenhuiskrans, near

Bredasdorp to the western edge of the nature reserve, an area of about 250 km^2. The property is owned by Armscor (Armaments Corporation of South Africa Ltd). The test site facility was established in 1983 (Greig 1984) and testing of missile-guidance systems occurs regularly (KA Shaw *in litt.*).

The lake comprises a long, narrow waterbody fed by the Sout and Potteberg Rivers in the north; in the south it is separated from the sea by a 2.5 km-wide vegetated dunefield (Figure D.1). The upper reaches of the Sout River are bordered by 30 m-high limestone cliffs through which the river winds before entering the lake. These cliffs persist on the eastern margin of the lake reaching nearly as far as Die Mond in the south and results in a near-vertical shoreline which is unsuitable for most waterbirds (Plate 6.1); only a small section south-east of Die Mond contains any shelving shoreline suitable for wading birds. In contrast, the western margin comprises more coastal plain, with sandy shores interspersed with loose-lying limestone rocks. Most waterbirds favour the sandy western shore; relatively fewer birds found on the eastern bank (Uys 1983, M Wheeler pers. comm.).

When full, the lake is approximately 18 km long and 0.5 km wide with a surface area of 750 ha (Figure D.1). Most of the water enters the lake via the Sout River, and its tributary the Potteberg River, which drain the wheat farming area in the Bredasdorp district. Both rivers are non-perennial and flow during the rainy season (April–September). The lake usually fills during the peak of the winter rains, June, July and August being the wettest three months. During inundation the lake is largely eutrophic as a result of agriculture run-off into the system and high primary productivity in the waterbody. The water in the lake is predominantly brackish with a pH of 9.2 (Uys and Macleod 1967) and salinity averages *c.* 5 parts per thousand (p.p.t.) (Uys 1983) Water-levels recede rapidly during the dry summer months when precipitation is low and evaporation levels high; levels can change from 7.0 m.a.s.l in October to less than 0.5 m.a.s.l. in February. During this period salinity increases and can change from 3 p.p.t. to 60 p.p.t. within a period of two months (DJ Coetzee *in litt.*). When water-levels recede, an island forms in the southern half of the lake, opposite the De Hoop homestead (Figure D.1) and attracts many waterbirds, particularly roosting ducks (M Wheeler pers. comm.). The island is dominated by couch grass *Cynodon dactylon*. The lake sometimes dries out completely (Uys 1983, AJ Williams *in litt.*) when extreme drought conditions persist.

Historically, reed- and sedge-beds were almost completely absent from the shoreline (Uys 1983) but stands of emergent vegetation are present on the eastern shoreline and in areas around freshwater springs (Ramsar 2010). These stands are dominated by *Phragmites australis* and *Juncus kraussi*. The dominant aquatic macrophyte is

Potamogeton pectinatus (Fennel-leaved pondweed) which occurs throughout most of the lake but varies in density according to salinities and herbicide run-off from adjacent agricultural activities. The edges of the lake comprise mainly riverine bush dominated by the milkwood tree *Calvaria inermis*. The surrounding vegetation is made up primarily of coastal fynbos, composed of various species of *Leucodendron*, *Protea*, ericas and restionaceous grasses. On the edge of the western shoreline there are dense stands of exotic rooikrans *Acacia cyclops*.

The lake is located near the eastern border of the WRR (Figure 1.2, Chapter 1). The region receives on average 380 mm of rain per annum. The WRR is described in detail in Chapter 1.

Methods

Waterbird surveys were carried out at De Hoop Vlei from April 1979 until January 2009. Survey frequencies varied during this period: from April 1979 to May 1990 surveys were made monthly, between May 1990 and January 1995 every four months, between January 1995 and January 2000 every six months, from January 2000 to April 2005 mainly at monthly intervals (with some gaps) and from March 2006 to January 2009 at six monthly intervals. The surveys carried out at six-monthly intervals represented mid-summer (January/February) and mid-winter (July/August) surveys. When they were done quarterly, the two additional surveys each year were carried in autumn (April) and in spring (September).

The gaps and discontinuities in the surveys, particularly after May 1990, stem from lack of resources and manpower to cover the site on a regular basis. The monthly surveys made during the 1980s formed part of the Southern African Waterfowl Census (SAWC) programme (Chapter 1). A total of 16 species were surveyed from the start of the programme (April 1979) but this was extended to include all waterbird species from April 1984 onwards.

Surveys generally took place in the morning starting at 0700 during the summer and 0800 during the winter and lasted 3–4 hours. They were conducted from the western edge starting at Die Mond in the south-east to as far north as Eselkamp in the north-west, depending on the water-level in the lake. Seven monitoring points were used (Figure D.1) and birds counted using 16×50 and 8×30 binoculars and a 16–50× telescope. When water levels rose and the northern half of the lake filled, sections from Eselkamp northwards were covered on foot and birds counted *en route*.

Species were divided into southern African residents and Palearctic migrants and grouped into three feeding guilds (Appendix 1.2, Chapter 1): herbivores, piscivores and invertebrate feeders. Seasonality, abundance and trend analyses follows closely that of Appendix A (see Methods). Overall waterbird abundance and diversity was assessed for the period April 1979 –January 2009 when all waterbird species were surveyed. Generalised linear models (GLMs) were used in trend analyses for the anatids, grebes, Red-knobbed Coot, Great White Pelican, Greater Flamingo and Lesser Flamingo and based on the surveys from April 1979–May 1990; trends for all other species were based on the period June 1985–January 1990. Emphasis is placed on the 16 species counted during the SAWC due to the duration and consistency of the surveys which reflected more meaningful seasonal patterns and aided interpretation of long-term trends. This group also constituted all of the species whose populations were used in designating the lake as a Ramsar site, and provided a basis for assessing the lake's Ramsar status over the last 30 years.

To demonstrate the global and regional conservation importance of De Hoop Vlei for waterbirds the Waterbird Conservation Value (WCV) score was used. Methods for the calculation of this score are described in Chapter 2 (see Methods). Regional (Western Cape) importance of species' populations at De Hoop Vlei were assessed using census data from CWAC (unpubl. data, Appendix 1.3, Chapter 1).

Results

Overall waterbird abundance and species richness

A total of 215 surveys (April 1979–January 2009) was carried out which comprised 107 summer surveys and 108 winter surveys. Of the 215 surveys, the initial 62 (April 1979–May 1984) included up to 18 waterbird species (Table D.1), while the following 153 surveys (June 1984–January 2009) incorporated all waterbird species present at the site; the latter comprised 77 summer surveys and 76 winter surveys.

A total of 83 waterbird species were recorded at De Hoop Vlei (Table D.1). African residents comprised 65 species (78%) and Palearctic migrants 18 species (22%). Considering surveys since June 1984 when all waterbirds were censused, 44 species were recorded in less than 25% of the surveys (Table D.1). The mean and maximum number of species recorded in summer and winter were similar (summer $\bar{x}$ = 29 and max. = 45, winter $\bar{x}$ = 27 and max. = 44).

On average, 5 710.2 ± 909.6 waterbirds were recorded during summer and 5 203.9 ± 534.3 during winter (Table D.1). The month with the largest average count of waterbirds was January (6 679 birds) while the month with the lowest average count was April (4 169 birds). The highest summer count was in December 1982 (19 149 birds) and the highest winter count was 28 418 in May 1979. Of the regional guilds, resident species dominated numerically in both summer and winter, accounting for 90% of all birds during the summer and 99% during the winter (Table D.1). Waterfowl dominated the wetland avifauna and comprised, on average, 83% and 87% of the total number of waterbirds during summer and winter respectively (Table D.1).

Seasonal variation in abundance

Overall, waterbird numbers did not reveal a strong seasonal pattern of occurrence. Abundance showed an increase from September–December and then stabilised from January–August; a peak in May was evident (Figure D.2). The abundance of some waterbird species showed marked seasonal change and these are reported below for resident species and Palearctic migrants.

Residents

Overall, the waterbird avifauna at the lake was dominated by residents. Abundance peaked from November–December with a decline in January and a winter peak in May (Figure D.2). *Waterfowl*

Waterfowl dominated this guild during summer and winter, comprising 80% and 86% of all waterbirds at the lake respectively. Consequently, the patterns of occurrence of species in this guild were the primary driving factors of waterbird populations at the lake. Within this guild, ducks and geese revealed a strong seasonal pattern; numbers increased in summer (with a peak in February) followed by a decline in numbers from April–September. Red-knobbed Coot was the dominant species in the guild, and accounted for 45% and 58% of all waterbirds during summer and winter respectively (Table D.1); its pattern of occurrence strongly mirrored that of all resident waterbirds (Figure D.3).

Of the waterfowl, five species (Egyptian Goose, Spur-winged Goose, Southern Pochard, Yellow-billed Duck and Maccoa Duck) exhibited clear seasonal patterns; Egyptian Goose peaked from January–March, Spur-winged Goose from March–May, Southern Pochard from November–December, Yellow-billed Duck from February–May and Maccoa Duck from May–July (Figure D.4).

Egyptian Goose was most abundant during late summer (February; mean 680.7 birds) with a maximum count of 3 175 in February 1988 (Table D.1). Numbers declined rapidly from April and from August–November the lake population of Egyptian Goose averaged less than 250 birds. Influxes to the lake started in December but by January most of the birds had arrived (Figure D.4).

Most Southern Pochards occurred in early summer. On average, 149 birds were recorded during December with a maximum count of 988 birds in November 1986 (Table D.1). Numbers declined sharply after January with less than 120 birds/month recorded from February to July. Maximum counts did show that up to 451 birds were present during this period.

Maccoa Duck was the only duck that showed winter peaks; most birds were present during May (mean 70 birds) with a maximum count of 875 in July 1979 (Table D.1). Numbers declined from October and the species was virtually absent from the lake during summer (mean of 5 birds/month from September to March).

No clear seasonal patterns were discernable for Cape Teal, Red-billed Teal, South African Shelduck and Red-knobbed Coot; Cape Teal and South African Shelduck exhibited the most erratic occurrence pattern of all the waterfowl species (Figure D.4). For five species (Common Moorhen, White-faced Duck, Fulvous Duck, Hottentot Teal and White-backed Duck), numbers were too small (mean <10 birds per month) to determine a meaningful seasonal patterns of occurrence.

The three grebe species showed variable patterns of seasonality. Black-necked Grebe showed two peaks: one in early summer (from November–December) and one in early winter (from May–June) (Figure D.5. On average, both peaks supported similar numbers of birds with 181 birds present during November and 177 birds during June (Table D.1). Numbers of Black-necked Grebe were at their smallest from January to March. Little Grebe were more abundant in winter, with peak numbers from July–August (Table 1; Figure D.5). A maximum of 675 birds was recorded in August 1988. No seasonal pattern of occurrence was evident for Great Crested Grebe; numbers remained relatively stable between summer and winter although they fluctuated throughout the year (Table D.1; Figure D.5).

Cormorants and darter

Reed Cormorant and White-breasted Cormorant showed a weak seasonal pattern, with higher abundance, on average, during winter (May–September) (Figure D.5); maxima of 584 and 455 were recorded in March 1987 and September 1987 respectively. African Darter occurred in numbers that average less than 10 birds but exhibited winter dominance; numbers, on average, peaked in July; a maximum of 169 was recorded in April 1987.

Great White Pelican

Great White Pelican was more abundant during late summer through to early winter (January–June, $\bar{x}$ = 35 birds/month) (Figure D.3). From July–December an average of 10 birds was recorded per month. A maximum of 435 birds was recorded in January 2001.

Resident shorebirds

Overall, resident shorebirds did not show any clear seasonal patterns of abundance and numbers fluctuated throughout the year (Figure D.3). Their numbers were small ($\bar{x}$ = 132 birds/month) and they constituted a tiny proportion in both summer (1.6%) and winter (1.5%) waterbird populations at the lake (Table D.1). They did dominate shorebird populations during winter when most of the migrant shorebirds had departed (Figure D.3).

Black-winged Stilt, Pied Avocet and Blacksmith Lapwing were the most abundant resident shorebirds throughout the year. They accounted for 61%, 17% and 13% of this group in summer, and 56%, 15% and 16% in winter, respectively (Table D.1, Figure D.6). None of the three species showed any strong evidence of seasonality; they occurred throughout the year but numbers fluctuated and peaks occurred erratically (Figure D.6); April was usually the month with smallest counts. White-fronted, Kittlitz's and Three-banded Plovers occurred in too small numbers (mean < 10 birds) for seasonality to be determined (Table D.1).

Waders

Greater and Lesser Flamingos showed clear but contrasting seasonal occurrence patterns. On average, Greater Flamingos were more abundant from August–January, with peaks in November, while Lesser Flamingos numbers were largest from April–August with peaks in May (Figure D.6). The maximum number of Greater Flamingos was 2 454 birds recorded in November 1984. For Lesser Flamingos, a maximum of 1 715 individuals was counted in October 1984 (Table D.1).

No seasonal abundance was evident for Grey Heron which, on average, showed relatively stable numbers throughout the year. However, maximum counts showed that more birds may be present between December and March (Figure D.6). African Spoonbill numbers showed a late summer (March) peak ($\bar{x}$ = 75) with numbers increasing from December (Figure D.6; a maximum of 368 birds was recorded in April 1987. African Sacred Ibis was more abundant during summer than winter with a strong February peak ($\bar{x}$ = 95) (Figure D.6); the maximum count was 499 birds in February 1985.

Little Egret was most abundant from February–March; numbers peaked in March ($\bar{x}$ = 44), but this species did exhibit influxes during winter (Figure D.6); up to 217 birds

(Table D.1) were recorded in July 1988. Yellow-billed Egret exhibited a strong pattern of seasonal occurrence being most abundant during autumn April/May; numbers did fluctuate throughout the rest of the year; a maximum of 72 birds was recorded at the lake (Table D.1). Numbers for Water Thick-knee, Great Egret, Hadeda Ibis, Glossy Ibis and Hamerkop were too small (mean < 5 birds per month) for clear seasonal patterns to be determined.

The only abundant gull at the lake was Kelp Gull. Although this species showed no clear seasonal patterns of abundance, Abundance was largest during the winter months (April to September) with peaks in September (Figure D.5); a maximum of 206 birds was recorded in September 1987. The other two gull species recorded at the lake, Hartlaub's Gull and Grey-headed Gull occurred in small numbers (mean < 10 birds/month) with Grey-headed Gull being the more abundant (Table D.1). Although numbers of birds were small, the data suggested that Hartlaub's Gull occurred mainly during summer.

Palearctic migrants

Migratory Palearctic species showed obvious seasonal abundance, occurring mainly during the summer months (September–April), with some birds remaining during the winter (Figure D.2). White-winged Terns and Curlew Sandpipers dominated this guild and comprised 46% and 36% of all Palearctic migrants respectively at the lake during the summer (Table D.1).

Migrant shorebirds peaked from December–January and were generally more abundant than resident shorebirds from October–January (Figure D.2, Table D.4). The most numerous migratory shorebirds were Curlew Sandpiper, Little Stint and Common Greenshank (Table D.1). Curlew Sandpiper numbers peaked from December–January; Little Stint numbers showed no obvious peaks and remained stable throughout the summer although their numbers fluctuated monthly (Figure D.8). Common Greenshanks occurred in greatest numbers from November–December and decreased rapidly after January (Figure D.8).

Numbers of White-winged Terns peaked in October with numbers gradually decreasing until April (Figure D.8). On average, 143 birds were counted during the summer surveys, with a maximum of 891 being counted in October 1985. Birds usually arrived in small numbers in September; most birds had departed by April.

Eight other Palearctic shorebirds were recorded. Their numbers were too small (summer mean <1) to warrant any further discussion.

Feeding guilds

Of the three feeding guilds, herbivores dominated during winter and summer, and mirrored the overall annual waterbird patterns at the lake (Figure D.9). Invertebrate feeders were the next numerous guild and dominated from October–February with fewer during winter. The piscivores were the least numerous guild and although numbers did fluctuate during the year, they were more abundant during winter and early summer (May–September) (Figure D.9).

Inter-annual variation in abundance

Overall, there was a decreasing number of waterbirds across the monitoring period at the lake (Figure D.10a). Resident species showed a significant downward summer trend ($r = -0.48$, $p < 0.05$) while winter populations showed greater fluctuations (Figure D.10). Mean summer populations declined from 8 739 in the 1980s to 4 391 in the 2000s, a decrease of 49%; winter populations declined by 48% (Figure D.10). The Palearctic migrants also showed a significant declining trend in their summer populations ($r = -0.57$, $p < 0.01$).

Resident species

Waterfowl

Of the waterfowl, only Egyptian Goose showed any evidence of an increase in the number of birds at the lake. Significant positive trends were noted during summer ($r = 0.54$, $p < 0.01$). Numbers fluctuated during summer and peaks to occur every 5–6 years, however there was a two year gap between peaks in 1993–1995 (Figure D.11). Populations of Southern Pochard, Cape Shoveler, Red-knobbed Coot, Yellow-billed Duck and South African Shelduck decreased at the lake. Numbers of Southern Pochard declined from an average of 249 birds in the summer months of the 1980s to 13 during the 2000s, a decrease of almost 95% (Figure D.11); this trend was significant ($r = -0.74$, $p < 0.001$). Since 2002, less than five birds have been seen at the lake during any one year. Like Egyptian Goose, numbers of pochard fluctuated between years and peaks tended to occur every four years. Cape Shoveler numbers fluctuated from 1979–1998; thereafter they showed a steady decline (Figure D.11). The species revealed both significant summer ($r = -0.53$, $p < 0.01$) and winter ($r = -0.42$, $p < 0.05$) downward trends. Numbers of Red-knobbed Coot prior to 1983 averaged *c.* 10 000 birds but showed a sharp decline after 1983 (Figure D.11). From 1983 to 1995 numbers fluctuated below 8 000 before another decline in 1996. After this, populations were never more than 2 000 birds. Their summer and winter populations showed significant downward trends ($r = -0.75$, $p < 0.001$ and $r = -0.66$, $p < 0.001$, respectively). Yellow-billed Duck showed more irregular inter-annual fluctuations both during summer and winter (Figure D.11); their summer population showed a significant declining trend in abundance ($r = -0.51$, $p < 0.01$). South African Shelduck numbers during summer declined significantly ($r = -0.59$, $p < 0.01$); winter numbers were generally small and showed two sporadic peaks, one in 1998 and the other in 2002 (Figure D.11). Other waterfowl species showed variable inter-annual fluctuations and trends in their populations could not be assessed.

There were significant downward trends for the Greater Flamingo during summer ($r = -0.52$, $p < 0.01$) and winter ($r = -0.42$, $p < 0.05$). Lesser Flamingos showed similar trends which were more significant during winter ($r = -0.51$, $p < 0.01$) than during summer ($r = -0.45$, $p < 0.05$). Greater Flamingos showed slightly more seasonal variability between years than Lesser Flamingo; both species were almost absent from the lake after 1985 (Figure D.11).

Black-necked and Little Grebes showed significant declining trends at the lake (Figure D.12). Black-necked Grebe showed declines in summer ($r = -0.41$, $p < 0.05$) and in winter ($r = -0.47$, $p < 0.05$) while Little Grebe displayed a decreasing trend in summer ($r = -0.44$, $p < 0.05$). Little Grebe showed greater inter-annual fluctuations than Black-necked Grebe. Great Crested Grebe revealed a strong fluctuating annual pattern of occurrence with summer and winter peaks at regular intervals; however from 1997–2004 numbers decreased to below 50 birds with a resurgence from 2005 (Figure D.12). No trend was evident for this species.

Numbers of Great White Pelican peaked at irregular intervals from 1979–1998 with numbers averaging below 60 birds. In 2000 and 2001 a large influx occurred and summer means of 72 and 167 birds were recorded after which numbers fluctuated annually. The trend, although not statistically significant, suggested that more Great White Pelicans were using the lake in 2000–2009 than in the earlier period.

The only additional species that showed evidence of declining trends were Kelp Gull and Grey Heron. Both Kelp Gull ($r = -0.41$, $p < 0.05$).and Grey Heron ($r = -0.45$, $p < 0.05$) showed decreasing trends in summer.

Palearctic migrants

Overall, Palearctic migrant species declined at De Hoop Vlei between 1979 and 2009 ($r = -0.57$, $p < 0.01$). Large fluctuations occurred annually. The summer of 1992 produced the largest mean count (2 596 birds) (Figure D.10). However, from 1993–2003 less than

100 shorebirds, on average, were recorded with a small peak in 2004/05. Generally, fewer Palearctic migrants, most of which comprised shorebirds, made use of the lake after 1993. Curlew Sandpiper ($r = -0.57$, $p < 0.01$), Common Greenshank ($r = -0.44$, $p < 0.05$) and Little Stint ($r = -0.40$, $p < 0.05$), which dominated the migrant shorebird population, all showed significant declines. Curlew Sandpiper and Little Stint showed similar annual patterns from 1987–1993 (Figure D.13). White-winged Tern showed a strong declining trend ($r = -0.66$, $p < 0.001$) and few occurred after 1992 (Figure D.13)

Feeding guilds

Of the three feeding guilds, the invertebrate feeders revealed a strong and significant declining summer trend ($r = -0.90$, $p < 0.001$; Figure D.14). Their numbers peaked from 1984–1991 (average of 2 499 birds), but then decreased to 931 birds during the 2000s, a decline of 63%. Winter populations showed a similar pattern (Figure D.14). The decline in numbers of Greater Flamingo and shorebirds over the study period contributed to the reduction in numbers of invertebrate feeders at the lake.

Herbivores showed large inter-annual fluctuations. The overall trend was downward although it was not as large as that of the invertebrate feeders. The average between 1998–2008 was 3 126 birds compared with 4 508 for 13-year period 1984–1997. The decline in the Red-knobbed Coot population contributed to this guild's steady decrease at the lake.

The piscivorous guild showed two peaks (1987–88 and 2006–08), almost 20 years apart, and were interspersed with smaller fluctuations. The peaks were attributed to large influxes of Great Crested Grebe, Reed Cormorant and White-breasted Cormorant during these times.

Trends per decade

Waterbird populations declined by almost 50% in both summer and winter over the 30-year period 1980–2000s (Table D.3). In spite of this overall reduction in waterbird abundance, four species, Egyptian Goose, Spur-winged Goose, Cape Teal and Great White Pelican showed increases between decades; overall they have shown at least a 40% increase in at least one of the seasons of the year since the 1980s (Table D.3).

Cape Shoveler, Southern Pochard, Red-billed Teal, Maccoa Duck, Red-knobbed Coot, Greater Flamingo and Lesser Flamingo decreased by more than 50% between the 1980s and the 2000s.These species also displayed decreases in each decade (Table D.3).

Waterbird Conservation Value (WCV) scores

Figure D.15 shows the WCVSs for each count from July 1984–January 2009. Scores fluctuated between and within years although certain peak years were evident (e.g. 1986–87 and 1989–90 and 2007) (Figure 7a). Of the 153 surveys, 148 (96%) scored greater than 1, while 84 surveys (54%) scored greater than 5. Six counts (4%) scored greater than 15 (Figure 7a), with five of these between July 1987 and Dec 1987, and the sixth count in August 2007. Sixteen species occurred at levels equal or greater to the global 1% threshold level (Table D.2).

Patterns of change are evident in term of species composition during the 25 year period. During 1984, Cape Shoveler, Yellow-billed Duck, Maccoa Duck, Red-knobbed Coot and Greater Flamingo were the most abundant and occurred regularly in numbers greater than the 1% threshold. From 1985–1992, the most abundant species included Cape Shoveler, Great Crested Grebe and Black-necked Grebe and to a lesser degree Caspian Tern. The 15-year period 1994–2009 revealed further changes with Caspian Tern, Great White Pelican and White-breasted Cormorant showing increased numbers at the lake. During this period there was a noticeable decline in the numbers of Cape Shoveler, Red-knobbed Coot and Yellow-billed Duck (Figure 7a).

Figures D.16a and D.16b show the relationship between the monthly 1% indices and the number of species reaching or surpassing the 1% threshold levels and total waterbird abundance respectively. This showed that although large indices (≥ 10) were usually associated with greater number of species reaching 1% threshold levels or larger numbers of waterbirds, this was not always the case; they can result from the occurrence of a small number (< 3) of species or lower overall count totals (< 5 000 birds/month); combined this occurred on three occasions: October 1986, February 2005, and July 2008. The February 2005 survey combined a low monthly count (2 080 birds) with a single species, Caspian Tern, contributing 8.47 to the overall scoring of 10.26 for that month. Although some surveys did not contain a single species reaching the 1% levels, the cumulative 1% index was always larger than 1.

Threatened species

De Hoop Vlei supported 12 species in threat categories (Barnes 2000): two Vulnerable species – African Marsh Harrier and Striped Flufftail, and 10 Near-threatened species – Black Harrier, Greater Flamingo, Lesser Flamingo, Cape Cormorant, Crowned Cormorant, Great White Pelican, Black Stork, Yellow-billed Stork, Greater Painted Snipe (Barnes 2000). The flamingos and pelican were the only species to use the wetland on a regular basis and in noteworthy numbers (Table D.1); the flamingos have become irregular visitors since 1986 (Figure D.11). The remainder of the species are probably rare, but annual, visitors to the lake (Table D.1).

Discussion

Seasonality, abundance and trends

The results demonstrated that De Hoop Vlei is an important wetland for resident waterbirds and less important for Palearctic migrant (Figure D.3). Resident waterbirds were numerically more abundant and on average outnumbered migrants 20:1 during the summer (September–March) when migrants were present. Heÿl (1988) suggested that overall waterbird numbers peaked at two-to five-year intervals. Results from this study for the period 1984–1995 suggested that these peaks do exist but from 1996–2009 were less evident (Figure D.10).

Waterfowl dominated the entire waterbird community at the lake (Figure D.3). Red-knobbed Coot was the most abundant species (Figure D.5); its dominance at the lake strongly reflected and influenced the overall occurrence pattern for all resident species and particularly the waterfowl group (Figure D.3). Uys and Macleod (1967) found the species to be present year-round with August–October peaks; data here reflected a November–December and a May peak (Figure D.5). Because the coot relied primarily on pond weed *Potamogeton* for both food and breeding material their occurrence is strongly linked to the abundance and availability of this macrophyte (Stewart and Bally 1985). Large numbers breed at the lake (Uys and Macleod 1967, CapeNature unpubl. data).

The strong seasonal pattern exhibited by the ducks and geese (Anatidae) (Figure D.4) confirmed Uys and Macleod's (1967) and Heÿl's (1988) summer peaks for this group. Egyptian Goose, Yellow-billed Duck and Cape Shoveler were the next most abundant species in this group and their monthly pattern of occurrence reported in this study was similar to those of Uys and Macleod (1967). Spur-winged Goose were largely absent at De Hoop Vlei in the 1950s; flocks up to 50 birds were reported in the early 1960s (Uys and Macleod 1967). During this study, the species occurred annually with flocks of up to 500 in late summer and early winter (Table D.1). Patterns of occurrence for Cape Teal, Red-billed Teal and South African Shelduck remained largely unchanged, although this study showed an April peak for shelduck compared with the January–February peak reported by Uys and Macleod (1967). Maccoa Duck had a stronger preference for the winter season at the lake compared with the regular year-round occurrence reported by Uys and Macleod (1967).

Generally, occurrence patterns of ducks and geese at the lake remained largely unchanged since the 1960s (Uys and Macleod 1967).

Although seasonal patterns of occurrence remained the same for most waterfowl, populations of many species declined over the study period. Red-knobbed Coot, Yellow-billed Duck, Cape Shoveler, South African Shelduck, Maccoa Duck and Southern Pochard all showed declines at the lake. These species were once common and abundant at the lake; the Cape Shoveler and Yellow-billed Duck were the two species motivated the Ramsar application in 1975 (Ramsar 2010).

While most waterfowl species decreased, notable increases in Egyptian Goose populations were evident. Populations of this species have increased throughout the Overberg (Magnall 1999, Magnall and Crowe 2001, CWAC unpubl. data, SABAP2 unpubl. data). At a site such as De Hoop Vlei long-term monitoring programmes enable the detection in changes of waterbirds, and notably congregatory species. Similar patterns have been noted at two other moult refuges for Egyptian Goose: Theewaterskloof Dam (Swanepoel et al. 2006) and at Dassen Island (Underhill et al. 2000). Their occurrence at the lake was presumably linked to the availability of food in the surrounding agricultural area. De Hoop Vlei falls within the Overberg wheat belt and harvesting at the end of the year (November–December) results in many grain-spilled stubble fields (Uys1983) and many waterfowl (notably Egyptian Goose) utilize the food resource and use the lake as a safe roosting refuge (Magnall and Crowe 2001). Similarly, farming activities have probably led to an increase in Spur-winged Goose numbers in the Overberg and not as a direct result of changing conditions at the lake itself.

Palearctic migrants at De Hoop Vlei did not contribute significantly to the overall waterbird population. Their fluctuating summer patterns suggested that they use the site as a temporary, staging site. Migrant shorebirds generally return to the same sites year after year (e.g. Elliott et. al. 1976). Thus, the years in which large numbers of Palearctic migrants occurred at De Hoop Vlei might follow a good breeding season in the northern hemisphere. Reproductive success of several Palearctic shorebirds is linked to lemming cycles in the tundra and display approximately three-year cycles (Underhill et al. 1987).

Several studies of the abundance of Palearctic shorebirds in the Western Cape have noted declines, both at localities which held small numbers of shorebirds and at sites such as Langebaan Lagoon, which hold large numbers (Underhill et al. 2001, Venter et al. 2002, Harebottle and Underhill 2006, Harebottle et al. 2006). If overall shorebird numbers decrease as a result of global climate change (for example the warming of the breeding areas in the tundra), then the overall smaller population will be accommodated at wetlands farther north, with decreases being most severe at the southernmost wetlands (Underhill 2003). De Hoop Vlei is the southernmost large wetland in Africa, at the end of the wader flyways from Eurasia. It is therefore more likely that the decreases in the numbers of Palearctic migrants at the lake are driven by factors occurring on the breeding grounds and migration routes rather than factors linked to habitat change at De Hoop Vlei.

Feeding guilds

Overall, herbivores and piscivores showed no well-defined seasonality with numbers fluctuating throughout the year. Invertebrate feeders were more abundant in summer than during the winter (Figure D.9), but this was mainly due to the influx of Palearctic migrants from October–March. The increase in herbivore populations from September–February is due to the increase in ducks and geese to the lake. The dominant herbivores were Egyptian Goose and Red-knobbed Coot during this period. Because Egyptian Goose generally feed at neighbouring crop fields during this time (Uys 1983), their input into the system was through defecation; these nutrients impact the water column and shoreline vegetation. Red-knobbed Coot feed at the lake and make direct impacts to the lake's nutrients through consumption of the aquatic plants and defecation in the water column.

The fairly large proportion of invertebrate feeders during winter was due to the seasonal abundance of Little Grebe and Cape Shoveler, rather than a reflection of high numbers of resident shorebirds or waders. During late winter and early parts of summer (August–November), when water-levels were high (3–4 m) shoreline availability decreased forcing shorebirds to find alternative shallow wetlands elsewhere, and leave the lake. This leaves open-water species to then feed on the invertebrates in the water that start to flourish as the macrophytic biomass increases due to increased freshwater and nutrient input (see Davies and Day 1998).

All three guilds showed regular inter-annual fluctuations during summer and winter; invertebrate feeders were the only guild to exhibit long-term declines (Figure D.14). The summer declines were associated with the decrease in Palearctic shorebird numbers (Figure D.13), together with the observed declines in abundance of Cape Shoveler, Black-necked Grebe, Little Grebe and Greater Flamingo (Figures D.11 and D.12). Winter declines were less striking because there was greater inter-annual variation. Both open water and shoreline species were impacted indicating changes in the food source rather than a habitat-induced change; there was little or no change to the major habitats at De Hoop Vlei (K.A. Shaw pers. comm.). Zooplankton formed the bulk of the diet for species in this guild; studies by Coetzee (1986) showed that the lake had a rich plankton community which consisted mainly of copepods and ostracods. He stated that this was the primary reason for the lake's rich waterbird community, but that the availability of these micro-organisms is dependent on salinity and water-level fluctuations.

Piscivores showed two striking winter peaks: one in the mid-1980s and then a larger influx in the mid-2000s (Figure D.14). During both these peaks the numbers of White-breasted Cormorant, Reed Cormorant and Great Crested Grebe increased. Scott and Hamman's (1988) study of fish found that Cape Kurper *Sandelia capensis* and Mozambique Tilapia *Oreochromis mossambicus* are the most common fish species, the former occurring naturally and the latter introduced in 1958. Other freshwater species were introduced (e.g. Smallmouth Bass *Micropterus dolomieu* and Largemouth Bass *M. punctulatus*) but did not survive (Scott and Hamman 1988). The tilapia adapt well to high salinities (Scott and Hamman 1988) and are therefore available throughout the year, especially during summer when salinities increase during dry-down conditions. The Cape Kurper is less tolerant to high water salinity but survives in pools from freshwater fountains in northern sections of the lake (Scott and Hamman 1988) and as the lake fills after the first winter rains the fish spawn and recruit to the lake system during winter and early summer. The winter peaks exhibited by the cormorants and Great Crested Grebe could well reflect years in which fish recruitment was high and when fish numbers declined in summer so did the number of fish-eating species at the lake.

Herbivore numbers showed the greatest amount of inter-annual variation although there is a tendency for a downward trend. This trend was linked to the decline in Red-knobbed Coots, Yellow-billed Duck and Southern Pochard (Figure D.11), the most abundant of the herbivores that fed at the lake. The increase in Egyptian Goose contributed to the increased variability of numbers in this guild; however they do not forage much at the lake (see above), so their influence on the herbivorous waterbird populations should be interpreted with care.

Environmental impacts on waterbirds at De Hoop Vlei

Overall, there are considerable fluctuations in the yearly abundance of certain waterbird species and feeding guilds. The changing hydrological conditions at the lake from one year to the next play a major role in determining waterbird occurrence and abundance at the lake. Depending on inundation patterns, and extreme events such as floods and droughts, water-levels and salinities can fluctuate widely annually (Coetzee 1983, Scott and Hamman 1988, A Scott *in litt.*). During the hot and windy summer months evaporation results in salinities reaching up 58 p.p.t.; during winter, inflow from the winter rainfall raises water-levels and salinities are reduced to 4 p.p.t. (Heÿl 1988, Coetzee 1986). These proximal factors impact on the physio-chemical properties of the water in the lake which then impact on aquatic plant growth and production of zooplankton and other micro-organisms. The net cumulative effect will then determine how waterbirds use the lake. Results from census work, such as undertaken here, are then able to produce a broad indication of the state of a wetland based on the status of the waterbird community over a period of time. A lack of suitable long-term quantitative data for these ecological variables prevented comparative analyses to be carried out for this paper; such analyses would assist in interpreting waterbird abundance and occurrence and make more informed recommendations. This is something that should be considered for future monitoring and reporting mechanisms.

Is there any evidence that rainfall has any influence on the occurrence of waterbirds at the lake? Uys and Macleod (1967) found that local flood events impact on movements of waterbirds in and out of De Hoop Vlei. In September 1957, during a flood event caused by unusually heavy winter rains, the lake overflowed and large areas to the west of the lake were extensively inundated and remained flooded for up to two years. The water took three years to recede and many large pools and pans were formed in this period. During the inundation period large numbers of waterbirds including Great Crested Grebe, Little Grebe Egyptian Goose, Cape Shoveler, Yellow-billed Duck, South African Shelduck, Red-knobbed Coot, Pied Avocet and Black-winged Stilt moved to the flooded area where they also bred. African Spoonbill, White-breasted Cormorant, Reed Cormorant and African Darter also moved from the lake and soon established heronries in the flooded vegetation. Some species such as Maccoa Duck and Grey Heron however remained on the lake during this period. Resident shorebirds such as Kittlitz's Plover, White-fronted Plover and Chestnut-banded Plover occurred in fairly large numbers in the inundated area during the drying phase but were largely absent when the flooding took place due to the lack of any shoreline. Few Blacksmith Lapwings were recorded on the Agulhas Plain and in the De Hoop Vlei in the 1960s (Uys and Macleod 1967); their numbers have since increased across the Western Cape (Underhill 2004).

Thus, birds will take advantage of temporarily flooded adjacent landscapes should they become available even though water-levels at De Hoop Vlei are high and able to support large numbers of waterbirds. These extreme flooding events are rare (Heÿl 1988) but during the late 1980s and early 1990s when high rainfall resulted in partial flooding of adjacent areas, waterbirds have been recorded feeding and breeding in these temporary inundated areas (A. Scott *in litt.*). The availability of suitable temporary habitat induced by flooding does therefore suggest that extreme rainfall events act as a catalyst for movements of waterbirds and impacts on the waterbird community at the lake, even though this is temporary. Waterbirds use these flooded areas due to the sudden availability and increased abundance of food, particularly invertebrates that arise due to the flooding. During flooding events, deeper water in the lake would limit benthic foragers and they would make use of shallower flooded areas elsewhere in the landscape to feed. Shoreline availability would also be reduced at the lake during this time and many of the shorebirds and waders would then move to adjacent areas of shallower water. In addition, it is possible that the availability of food is lower in the lake during these periods; dilution of the water column can result in lower productivity of macro-invertebrates (Davies and Day 1998). This decrease in food in the lake could further encourage birds to move to adjacent wetlands under these conditions. The lake does not offer many breeding opportunities (M Wheeler pers. comm.) and the creation of wet grassland and islands allows ducks and colonial breeders such as ibises, spoonbills and cormorants to breed locally (Uys and MacLeod (1967).

Inundation patterns at the lake change on an annual basis depending on the amount of rainfall and inflow into the system. In years of higher than average winter rainfall, higher water-levels persist during summer and, although water-levels recede, more waterbirds remain during this period (A. Scott *in litt.*). In contrast, in years with below average winter rainfall, and in drier summers, water-levels at the lake recede quicker. The lake dries up almost completely annually (AJ Williams *in litt.*). As the lake dries and water-levels recede to form small pools of water, open-water species need to find an alternative refuges (see below). Under these extreme drying conditions, brought on by lower annual rainfall, the lake becomes more suitable for some shorebirds and waders, but most waterbirds would need to move and seek alternative wetlands.

Thus the composition and abundance and of waterbirds at De Hoop Vlei is determined by the state or condition of the lake on an annual basis. Waterbirds will use the lake for the same purpose year after year, but as reported here, their numbers vary depending on the conditions present. The amount of rainfall, coupled with the frequency and amount of inundation at the lake, are important proximal factors in this regard.

Given that climate change forecasts predict drier winters with fewer and less intense rainfall events for the southwestern Cape Province (Midgley et al. 2005) impacts on waterbirds and the general ecology of De Hoop Vlei are likely to occur. Less frequent inundation would result in zooplankton, plant and fish communities declining and this would directly impact on the way in which waterbird populations use the lake. Waterbirds could undertake more frequent movements (particularly for open-water species) to other wetlands in the region as conditions at the lake deteriorate more rapidly than usual The cumulative effect of the predicted changes to regional climate would not only affect De Hoop

Vlei but other coastal wetlands in the region. With the drastic declines observed in some species and feeding guilds at the lake (see Results section) could we already see the start of such climate-induced changes or are these changes just a response to natural variability in wetlands? It seems likely, based on these waterbird declines, that the lake may be at a stage where, due to increasing variability in its ecology (e.g. more frequent dry-downs occurring due to precipitation being more erratic), it is unable to sustain the large waterfowl populations it once did and why the observed declines have occurred. Further ongoing monitoring of the lakes's fish fauna and macrophytic biomass, plus water quality measurements is encouraged to assess the long-term impacts of climate change on the systems ecology. The impact of phosphates and sulphates (fertilizers etc.) entering the system from agricultural run-off should not be ignored and should also be considered as part of a long-term monitoring programme at the site. Some eutrophication is usually beneficial to wetland systems stimulating growth of plankton and aquatic plants but excessive and regular nutrient enrichment could lead to deterioration in water quality and reduction in primary productivity in the lake and this impacts at higher trophic levels in the system (Davies and Day 1998).

Role of De Hoop Vlei in a regional context

De Hoop Vlei is one of the largest, natural permanent wetlands in the southeastern section of the winter rainfall region. When full, the lake is relatively deep (*c.* 8 m), but water-levels vary depending on flood conditions (Coetzee 1986). Because deeper water deters most waterbirds from feeding optimally (Ntiamoa-Baidu 1998, Colwell and Taft 2000), it is the amount and extent of open, mostly shallow water which attracts large numbers of waterfowl to the lake, particularly during the dry season (November–February) (Figures D.4 and D.5) when surrounding ephemeral wetlands dry out.

But how does De Hoop Vlei compare with other regional wetlands in terms of waterfowl abundance? The only other large wetland systems located close to the lake are Soetendalsvlei (34°43'S, 19°58'E) and the Brëëde River Estuary (34°24'S, 20°49'E). Soetendalsvlei is a large (*c.* 2 500ha) freshwater lake which lies 50km to the southwest of De Hoop Vlei, and about 10 km north of Cape Agulhas, the southernmost point in Africa. The lake is shallow (*c.* 2–3 m, LG Underhill pers. comm.) and consists largely of open water and dense reed and sedge islands and beds along the margins. The site is known for large waterfowl populations (M.Tripp pers. comm.) but few surveys have been carried out (CWAC unpubl. data). These surveys, which cover a subset of the lake, have recorded the following waterfowl with maxima exceeding 50 individuals during mid-summer (January/February): Egyptian Goose (maximum 503), Spur-winged Goose (251) and Yellow-billed Duck (180)

(CWAC unpubl. data). In contrast, the Breede River estuary, located 40 km to the east of De Hoop Vlei, is an open estuary which has typical estuarine habitats comprising mud and sand flats near the mouth, and deeper, less saline water with vegetated banks further upstream. The main section surveyed for waterbirds is approx. 850ha and the mean depth is about 3.0m (Carter 1983). Three waterfowl species have been recorded and with maxima of more than 50 individuals; Egyptian Goose (379), South African Shelduck (291) and Yellow-billed Duck (135) (CWAC unpubl. data). Numbers of waterfowl are expected to be lower in the estuary due to regular saline conditions as a result of tidal influences but, nevertheless, the estuary compares favourably with De Hoop Vlei and Soetendalsvlei. Thus, although nearby wetlands of comparable size, or larger in the case of Soetendalsvlei, support waterfowl populations they do not support nearly the same numbers as recorded at De Hoop Vlei. As such, the lake is the primary waterfowl locality in this area of the winter rainfall region and emphasizes the valuable role it plays in this regional context.

The lake is also used as a moulting site by Cape Shoveler and Egyptian Goose – up to 1216 and 1332 birds have been recorded at the lake respectively (Ramsar 2010). With no moult information available from Soetendalsvlei or Breede River Estuary, the moult data from De Hoop Vlei suggests that it is probably the primary moulting site for some waterfowl species in the region. De Hoop does support some breeding species (notably Red-knobbed Coot and Great Crested Grebe) but it generally is not considered an important breeding locality within the region (Uys 1983).

The lake acts as a refuge for non-breeding waterbirds from the summer rainfall region and, possibly the year-round rainfall region. Uys (1983) proposed that when drought conditions persist in the interior of South Africa, waterfowl in particular, would move to coastal wetlands. There are ringing recoveries for Egyptian Goose, Cape Shoveler, South African Shelduck and Red-billed Teal from the Agulhas Plain region of birds ringed at Barberspan Bird Sanctuary in the North-West Province (Underhill et al. 1999), a direct distance of nearly 1000 km. In addition, there are three long-distance (> 1 000 km) recoveries of Cape Shoveler from wetlands in the north-east of South Africa of birds ringed near Bredasdorp providing further evidence of a north-south movement (Underhill et al. 1999). Yellow-billed Ducks ringed in the Wilderness Lakes area, near Knysna on the south coast, show westward movement and some birds have been recovered in the Agulhas Plain region, a distance of over 300km. However, like the Barberspan recoveries, how regular these movements are and what proportion of the population undertake these movements still needs to be assessed and more intensive ringing studies will be needed to assess whether inter-rainfall region movement occurs regularly.

It is also possible that De Hoop Vlei could absorb Red-knobbed Coot populations from the Bot and Klein River estuaries when they are breached (see Chapter 4, CWAC unpubl. data). Between January and August 2004 the numbers of Red-knobbed Coot at De Hoop Vlei increased from 822 to 3 285, a four-fold increase (Figure D.11). This influx followed the breaching events at both the Bot and Klein River estuaries in August 2003 when approximately 15 000 coots were present on both estuaries prior to them being breached. When breached, coots leave the estuaries en masse as the wetlands become unfavorable due to high salinities under open-mouth conditions. Underhill et al. (1999) showed eastward movement of Red-knobbed Coot from Cape Town wetlands, with one recovery close to De Hoop Vlei. Although no ringing recoveries exist directly between Bot River and Klein River estuaries and De Hoop Vlei the it seems possible, based on the above, that some birds may disperse to De Hoop Vlei. The lake is about 150 km from both estuaries, a distance which can be covered by these birds which are strong nocturnal flyers (del Hoyo et al. 1996). There are three recoveries of coots ringed in Cape Town and found on the Agulhas Plain and Wilderness lakes (Underhill et al. 1999) which provides some evidence that coots do undertake eastward movements in the Western Cape province.

Review of the Ramsar criteria

De Hoop Vlei, together with Barberspan in the North West Province, was one of two wetlands designated as South Africa's first Ramsar sites in 1975, i.e. wetlands of international importance (Cowan 1995). Criteria for designation were based on the site (a) containing representative, rare or unique wetland types, (b) regularly supporting 20 000 or more waterbirds and (c) regularly supporting 1% of the individuals in a population of one species or subspecies of waterbird (Ramsar 2010). The main focus of the initial Ramsar application for De Hoop Vlei related to the lake's abundance of waterbirds, notably waterfowl for which the Cape Shoveler and Yellow-billed Duck fulfilled the 1% population threshold criteria. The last update to the Ramsar information sheet was undertaken in 1998 (Ramsar 2010) when the populations thresholds were reviewed and based on maxima the Cape Shoveler population was estimated to represent 7% of the global population and the Yellow-billed Duck 15%. The Red-knobbed Coot was also reported to occur regularly in numbers above 10 000. The current study provides additional data (from 1990–2009) and an opportunity to review the lake's Ramsar status.

Overall, total waterbird numbers showed a general decline between 1984 and 2009. On only one occasion (January 1990) did the total count exceeded 20 000 birds. Although numbers fluctuated due to changing conditions at the lake, fewer than 15 000 waterbirds were counted after 1993 (Figure D.10a) and mean abundance of waterbirds over the three decades (1980s–2000s) decreased by 43% (Table D.3).

Populations of Cape Shoveler and Yellow-billed Duck showed large decreases between 1980s and 2000s (Table D.3), and did not occur as abundantly in the1980s compared with the 2000s (Figure D.9). Cape Shoveler and Yellow-billed Duck occurred at 1% levels in the 2000s even though populations had declined since the 1980s. Numbers of Red-knobbed Coot last exceeded 10 000 birds in 1983 and showed 93% population declines over the three-decade study period (Figure D.11)

In addition, the conservation value score (Figure D.15) showed that there was been a shift in the species composition from the 1980s to the 2000s; a system dominated by ducks and coot in the 1980s was dominated by piscivores (cormorants, terns and grebes) in the 2000s. Does this suggest that De Hoop is no longer playing an important role for waterfowl species and could this potentially impact on its Ramsar status? During the study period, the lake may well have been undergoing ecological changes. However, at the end of the study period, the lake still appeared able to support large numbers of waterfowl and other waterbirds (Table D.2) and its Ramsar status did not seem threatened. However, should conditions at the lake deteriorate and fewer species reach the 1% threshold then its Ramsar status could be downgraded to the Montreux Record. Ramsar sites on the Montreux Record require affirmative action by the relevant management and conservation authority (in this case CapeNature) to improve conditions so as to restore the ecological character of the site in order to upgrade it back to full Ramsar status (Ramsar 2010).

The site was also designated an Important Bird Area (Site SA119, Barnes 1998, Fishpool and Evans 2001). Based on the data presented here (Table D.2) its IBA status was secure.

Waterbird conservation issues and future research recommendations

This study highlighted the importance of De Hoop Vlei as an important waterbird locality in the winter rainfall region, albeit numbers of certain species were declining. From a conservation perspective the lake benefited from its incorporation into the De Hoop Nature Reserve, proclaimed in 1957. It afforded waterbirds protection from threats such as recreational activities (boating and fishing), disturbance from cattle and feral dogs and cats, and hunting, commonly present at unprotected wetland sites (e.g. Anderson et al. 2003). The adjacent missile testing facility did pose a threat in terms of noise disturbance, but testing was carried out occasionally (AJ Williams *in litt.*). Since the missile testing range was constructed in 1984 waterbird numbers have fluctuated but generally have not led to a total abandonment of the site suggesting that it has not been a major threat to the lake's waterbird community. In fact, the site has indirectly afforded the lake some protection as there are fewer visitor disturbances on the western shoreline.

A conservation management plan was in place for the De Hoop Nature Reserve, including the lake, and is scheduled to be updated every five years (K.A. Shaw *in litt.*). Consequently, the conservation status of waterbirds remained favourable at the site based on the land tenure and proposed conservation plans and actions of the conservation authority. Possibly the greatest threat to waterbirds at the lake is the changing hydrological conditions, which are linked directly to activities in the catchment region. Water abstraction for crop irrigation and spread of alien invasive plants such as Rooikrans *Acacia cyclops* and Port Jackson *Acacia saligna* reduce run-off into the lake. Coupled with impacts of climate change, long-term changes to the lake's ecology could impact on the occurrence and abundance of waterbirds in the future; this needs to be closely monitored through the continuation of regular waterbird surveys

At the end of the study period, the monitoring of waterbirds was taking place by means of quarterly surveys in January, April, July and October, and were being conducted by staff of CapeNature. This survey frequency took account of the limited resources available to survey the waterbirds on a more regular basis, given the size of De Hoop Vlei and the difficulty of gaining access to some of the survey points. The monthly census data in this study (1979–1990) highlighted the seasonal and inter-annual value of data collected at this frequency to understanding the patterns of waterbird abundance. Count intervals longer than three months cannot be interpreted as well as monthly data, particularly in terms of determining seasonality and peak abundance. Consequently, for a site as important as De Hoop Vlei, I made the recommendation to CapeNature that the reinstatement of monthly surveys should be considered. This goal could be achieved by intensive staff training of staff. The benefits of having monthly surveys would enable the impact of perturbations, for example climate changes, to be assessed. The existence of the excellent baseline survey data, which was analysed for this paper, would increase the value of ongoing monthly surveys. The particular significance of De Hoop Vlei is that it is the southernmost large wetland in Africa, situated close to Cape Agulhas

The long-term waterbird survey datasets existed for the site, one shortcoming of this analysis was the lack of a continuous record of physical and ecological data (e.g. water-levels, salinities, turbidity, and biomass of lake flora and fauna). This made it difficult to make meaningful interpretations of the status waterbird occurrence at the lake. A more systematic and integrated monitoring programme (IMP) would be needed at De Hoop Vlei to better understand the inter-relationships between the lake and its biota. This integrated approach has been identified as a critical way forward in managing wetlands for waterbirds both in the United States (Parsons et al. 2002, Erwin 2002) and in the United Kingdom (Kershaw et al. 2001), the latter focusing on Anatidae. Such an approach would lead to improved scientific data collation and hence more effective management of the site for waterbirds.

One way to coordinate an IMP would be to establish De Hoop Vlei as a bird observatory. Bird observatories have been established around the world where their primary purpose is to conduct long-term monitoring of bird populations and migration (Chambers 2005, Knudsen et al. 2007, http://www.birdobscouncil.org.uk/). They are usually located on defined or prime migration routes. Because of its southernmost position in Africa and its role in supporting regular numbers of Palearctic waterbird species (notably shorebirds), De Hoop has the potential to play a useful role in intensively monitoring changes in migrant waterbird populations, especially in an era of rapid climate and environmental change (Chambers 2005). Besides migrant species, more intensive monitoring of local resident waterbirds is recommended. This would lead to an improved understanding of the occurrence and movements of resident species, especially in a regional context. Provincial nature conservation agencies, like CapeNature, have responsibilities to conserve and manage local indigenous avifauna and should feature prominently in their their biodiversity policies. To date no bird observatory has been established in South Africa and although funding and personnel resources will be required, a strategy should be put in place by provincial and national authorities to start developing such a proposal.

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Table D.1 Summary of waterbird surveys for De Hoop Vlei from 1979–2009. Species in bold were counted from 1979–2004 (N=215, n=107 summer, n=108 winter); those not in bold from 1985–2004 (N=153; n=79 summer, n=79 winter) (see text for details). Species marked with an asterisk (*) were recorded on fewer than 25% of surveys. Species sorted in descending order of mean summer abundance per guild.

Species	Summer		Winter	
	Mean ± S.D.	Min-Max[1]	Mean ± S.D.	Min-Max[1]
Residents				
Waterfowl				
Red-knobbed Coot	4775.2 ± 838.7	0–14400	5962.6 ± 782.7	0–24200
Cape Shoveler	680.7 ± 175.6	0–3004	532.4 ± 23.2	0–2174
Egyptian Goose	647.7 ± 482.6	0–3175	341 ± 123.6	0–2113
Yellow-billed Duck	632 ± 448.9	0–4626	503.9 ± 198.1	0–3114
Southern Pochard	149 ± 118.5	0–988	63 ± 65.3	0–789
Little Grebe	120.5 ± 33.4	0–597	170.8 ± 36.6	0–675
South African Shelduck	71.9 ± 35.3	0–478	19.8 ± 13.7	0–896
Great Crested Grebe	57.7 ± 9.1	0–276	49.1 ± 9.5	0–319
Black-necked Grebe	54.7 ± 36.9	0–806	73.8 ± 45.9	0–581
Cape Teal	35.5 ± 12.1	0–472	32 ± 4.4	0–163
Spur-winged Goose	33.9 ± 30.1	0–545	60.6 ± 33	0–696
Red-billed Teal	27.2 ± 18.1	0–540	21.3 ± 9.5	0–604
Maccoa Duck	12.1 ± 13.7	0–127	59.3 ± 10.2	0–895
Common Moorhen*	1.7 ± 1.6	0–52	1.2 ± 0.8	0–13
White-backed Duck*	0.4 ± 0.4	0–11	0.2 ± 0.3	0–13
White-faced Duck*	0.3 ± 0.6	0–30	0.2 ± 0.3	0–8
Fulvous Duck*	0.1 ± 0.1	0–3	0.1 ± 0.1	0–1
Hottentot Teal*	–	–	0.2 ± 0.3	0–8
Sub-total	**4692.5 ± 665**	**0–14934**	**4675.8 ± 463.9**	**0–12950**
Pelicans				
Great White Pelican	26.8 ± 23.4	0–435	27.3 ± 16.2	0–296
Cormorants and darter				
White-breasted Cormorant	63.6 ± 23.5	0–433	87.3 ± 7.1	0–506
Reed Cormorant	38.4 ± 18.4	0–584	76.7 ± 17.1	0–434
African Darter	4.3 ± 3.2	0–28	9.6 ± 4.4	0–169
Crowned Cormorant*	2.4 ± 2.8	0–99	1.2 ± 1.7	0–18
Cape Cormorant*	2.1 ± 4.7	0–157	1.2 ± 1	0–20
Sub-total	**110.6 ± 45.4**	**0–690**	**175.8 ± 23.6**	**0–1109**
Shorebirds				
Black-winged Stilt	76.5 ± 26.4	0–370	79.9 ± 25.6	0–304
Pied Avocet	20.5 ± 8.7	0–199	22.1 ± 7.3	0–173
Blacksmith Lapwing	17 ± 6.2	0–237	24.2 ± 4.1	0–130
Kittlitz's Plover	4 ± 1.7	0–36	7.7 ± 1.5	0–71
Three-banded Plover	3.3 ± 2.4	0–78	3 ± 2.1	0–39
White-fronted Plover	2.7 ± 4.3	0–140	9.1 ± 3.1	0–69
Water Thick-knee	1.6 ± 0.9	0–10	1.4 ± 0.7	0–16
African Snipe*	0.2 ± 0.3	0–9	–	–
Greater Painted-snipe*	0.1 ± 0.1	0–1	–	–
Sub-total	**125.4 ± 35.3**	**0–414**	**147.1 ± 22.9**	**0–457**

Table D.1 contd

Species	Summer		Winter	
	Mean ± S.D.	Min-Max	Mean ± S.D.	Min-Max
Waders				
African Spoonbill	38.5 ± 22.4	0–253	36.8 ± 8.9	0–368
African Sacred Ibis	38.4 ± 27.4	0–499	20.4 ± 17.2	0–474
Grey Heron	34.9 ± 6.5	0–188	31.8 ± 5.4	0–206
Little Egret	21.2 ± 12.7	0–148	20.1 ± 7.3	0–217
Cattle Egret	17.4 ± 8.7	0–174	8.4 ± 6	0–189
Yellow-billed Egret	6.8 ± 4.8	0–54	6.6 ± 4.4	0–72
Black-crowned Night-Heron*	3.4 ± 3.9	0–39	8.7 ± 2.2	0–161
Great Egret*	2.7 ± 1.5	0–37	0.7 ± 0.5	0–32
Glossy Ibis*	2.1 ± 2.7	0–33	1.5 ± 1	0–21
Black-headed Heron*	0.8 ± 0.8	0–13	0.5 ± 0.5	0–11
Hamerkop	0.7 ± 0.4	0–15	1.5 ± 0.4	0–10
Black Egret*	0.5 ± 0.8	0–15	0.5 ± 0.9	0–15
Hadeda Ibis*	0.5 ± 0.5	0–6	0.5 ± 0.3	0–11
Purple Heron*	0.3 ± 0.3	0–5	0.7 ± 0.2	0–9
Black Stork*	0.2 ± 0.1	0–2	0.2 ± 0.1	0–2
Little Bittern*	0.1 ± 0.2	0–3	0 ± 0	–
Yellow-billed Stork*	0.1 ± 0.2	0–3	0 ± 0	–
Sub-total	**167.9 ± 60.3**	**0–976**	**138.3 ± 16.3**	**0–1038**
Flamingos				
Greater Flamingo	193.5 ± 98	0–2454	138.3 ± 97.6	0–1473
Lesser Flamingo*	51.2 ± 42.7	0–1715	118.9 ± 30.3	0–1715
Sub-total	**244.6 ± 100.0**	**0–2482**	**257.2 ± 90.0**	**0–1875**
Rallids				
Striped Flufftail*	0.1 ± 0.1	0–1	–	–
African Rail*	–	–	0.1 ± 0.1	0–1
African Purple Swamphen*	0.1 ± 0.1	0–1	0.1 ± 0.1	0–1
African Jacana*	–	–	0.1 ± 0.1	0–1
Sub-total	**0 ± 0**	**0–1**	**0.1 ± 0.1**	**0–1**
Gulls				
Kelp Gull	19.1 ± 9.3	0–62	28.8 ± 4.4	0–206
Grey-headed Gull	2.7 ± 1	0–29	2.9 ± 1.3	0–26
Hartlaub's Gull*	0.2 ± 0.2	0–8	0.1 ± 0.1	0–3
Sub-total	**22 ± 8.9**	**0–68**	**31.7 ± 3.3**	**0–234**
Terns				
Whiskered Tern*	8.9 ± 22.2	0–427	–	–
Caspian Tern	6.2 ± 5.2	0–127	6.1 ± 5	0–82
Swift Tern*	1 ± 2.6	0–160	–	–
Sub-total	**16 ± 24.5**	**0–433**	**6.1 ± 5**	**0–82**
Raptors				
African Fish Eagle	1.7 ± 0.5	0–7	1.7 ± 0.5	0–12
African Marsh-Harrier*	0.3 ± 0.3	0–9	0.1 ± 0.1	0–1
Black Harrier*	0.1 ± 0.1	0–1	0.1 ± 0.1	0–1
Sub-total	**2 ± 0.6**	**0–16**	**1.8 ± 0.6**	**0–12**

Table D.1 contd

Species	Summer		Winter	
	Mean ± S.D.	Min-Max	Mean ± S.D.	Min-Max
Palearctic migrants				
Shorebirds				
Curlew Sandpiper	273.9 ± 140	0–2466.	25.2 ± 9.1	0–507
Little Stint	123.1 ± 54.7	0–1043	13.3 ± 4.7	0–352
Common Greenshank	13.2 ± 10.2	0–110	3.9 ± 7	0–122
Ruff*	8.8 ± 4.8	0–132	0.7 ± 1.3	0–120
Marsh Sandpiper*	7.5 ± 8.3	0–179	1.7 ± 3.3	0–370
Sanderling*	6.5 ± 9.6	0–316	2 ± 3.9	0–92
Common Ringed Plover*	2.6 ± 4.2	0–140	0.2 ± 0.3	0–9
Grey Plover*	0.8 ± 2	0–45	0.1 ± 0.2	0–3
Wood Sandpiper*	0.2 ± 0.4	0–13	–	–
Bar-tailed Godwit*	0.1 ± 0.3	0–10	0.1 ± 0.1	0–1
Ruddy Turnstone*	0.1 ± 0.2	0–2	–	–
Red Knot*	0.1 ± 0.1	0–1	0.1 ± 0.2	0–3
Eurasian Curlew*	0.1 ± 0.1	0–1	–	–
Common Sandpiper*	0.1 ± 0.1	0–3	0.2 ± 0.4	0–8
Sub-total	**436.5 ± 198.7**	**0–3180**	**46.9 ± 17**	**0–904**
Terns				
White-winged Tern	143.1 ± 60.4	0–891	0.1 ± 0.1	0–400
Common Tern*	1.4 ± 2.4	0–71	–	–
Sandwich Tern*	0.1 ± 0.2	0–10	–	–
Sub-total	**144.5 ± 60.4**	**0–891**	**0.1 ± 0.1**	**0–400**
Raptors				
Osprey*	0.1 ± 0.1	0–2	–	0–1
Sub-total: residents	**5129.3 ± 685.3**	**0 –14972**	**5157.1 ± 525.2**	**2–13774**
Sub-total: Palearctic migrants	**581 ± 248.8**	**0 –3830**	**46.9 ± 17**	**0– 988**
Total : all waterbirds	**5710.2 ± 909.6**	**0 –16338**	**5203.9 ± 534.3**	**7–13792**

[1] The sub-total values here reflect the minimum/ maximum number for the group profile as a whole and not the sum of individual minima/maxima for each species which would represent estimated min./max. carrying capacity and not actual min./max. numbers reflected by the dataset

Table D.2 Species of conservation importance at De Hoop Vlei based on maximum counts from 215 surveys. Ramsar 1% levels, sub-regional IBA levels and provincial (Western Cape) thresholds are given. Species are sorted in descending order of the global 1% threshold level. Species in bold are included in the South African Red Data book (Barnes 2000).

Species	Max. count	Threshold		
		Ramsar 1% [1]	IBA 0.5%[2]	Western Cape[3]
Maccoa Duck	895	9% (14)	17	105%
Cape Shoveler*	3004	8.6% (135)	173	37%
Greater Flamingo	2454	3.2% (18)	30	13%
Lesser Flamingo	1715	2.9% (7)	17	26%
Caspian Tern	127	8.5% (16)	27	23%
Black-necked Grebe	806	5.4%(18)	28	25%
Yellow-billed Duck	4626	4.6% (43)	89	33%
Whiskered Tern	427	4.3% (4)	7	52%
White-breasted Cormorant	506	4.2% (30)	49	10%
Great Crested Grebe	319	3.2% (35)	63	24%
Red-knobbed Coot	24200	2.4% (42)	86	33%
Great White Pelican	435	2.2% (4)	11	13%
Southern Pochard	988	2% (10)	38	59%
South African Shelduck*	896	1.8% (1)	10	9%
Black-winged Stilt	370	1.6% (13)	38	8%
Pied Avocet	199	1.1% (1)	9	4%
Egyptian Goose	3175	–	17	10%
Spur-winged Goose	696	–	8	15%
Little Grebe	675	–	6	14%
White-fronted Plover	140	–	1	9%
Curlew Sandpiper	1732	–	1	3%
Black Egret	15	–	–	300%
Black-crowned Night-Heron	161	–	–	57%
Great Egret	37	–	–	44%
Whitefaced Duck	30	–	–	26%
Marsh Sandpiper	370	–	–	26%
White-winged Tern	891	–	–	26%
Grey Heron	206	–	–	18%
African Spoonbill	368	–	–	18%
Red-billed Teal	604	–	–	15%
Little Egret	217	–	–	14%
African Sacred Ibis	499	–	–	11%
Reed Cormorant	584	–	–	10%
Cape Teal	472	–	–	9%
Fulvous Duck	3	–	–	9%
African Darter	169	–	–	9%
Hottentot Teal	8	–	–	7%
Little Stint	700	–	–	5%
White-backed Duck	13	–	–	2%

[1] Figures represent the percentage of the estimated global* or Southern African# population based on the maximum count. Number in parentheses represents the number of surveys which met or surpassed the 1% threshold level. Calculated from Wetlands International (2006).

[2] Figures represent the number of surveys which met or surpassed the Sub-regional IBA level (0.5% threshold) for southern Africa (Barnes 1998) but did not surpass the 1% global threshold level.

[3] Value represents the percentage of the estimated provincial population and based on the maximum count. Estimates sourced and calculated from Coordinated Waterbird Counts, Animal Demography Unit, unpublished data (2006)

Table D.3 Comparison of mean abundance of 14 waterbirds and total waterbird population at De Hoop Vlei during three decades (1980s, 1990s and 2000s) and the percentage change between decades.

Species	Season	Mean abundance			% change		
		Decade			Decade		
		1980s	1990s	2000s	1980s–1990s	1990s–2000s	1980s–2000s
Cape Shoveler	S	918.2	822.3	288.0	–10.44%	–64.98%	–68.64%
	W	612.5	510.2	251.1	–16.71%	–50.78%	–59.00%
Cape Teal	S	30.3	38.0	59.1	25.34%	55.46%	94.85%
	W	34.2	43.0	25.8	25.57%	–0.04%	–24.71%
Egyptian Goose	S	711.4	1016.9	1541.0	42.94%	–51.54%	–116.61%
	W	266.7	598.9	371.2	124.58%	–38.03%	39.18%
Maccoa Duck	S	6.6	1.8	2.4	–72.88%	31.69%	–64.28%
	W	93.0	8.5	16.9	–90.81%	98.16%	–81.80%
Red-billed Teal	S	23.3	101.0	6.6	332.36%	–93.51%	–71.92%
	W	16.0	40.4	10.5	152.21%	–73.94%	–34.28%
Red-knobbed Coot	S	6502.0	2397.4	1123.5	–63.13%	–53.14%	–82.72%
	W	8044.0	2787.9	1777.8	–65.34%	–36.23%	–77.90%
South African Shelduck	S	91.0	15.4	35.9	–83.07%	133.04%	–60.56%
	W	16.7	65.7	15.7	292.82%	–76.13%	–6.24%
Southern Pochard	S	237.3	69.7	13.1	–70.65%	–81.18%	–94.47%
	W	85.8	42.6	48.9	–50.28%	14.62%	–43.01%
Spur-winged Goose	S	25.3	36.8	94.9	45.24%	158.10%	274.86%
	W	68.6	68.2	35.2	–0.56%	–48.35%	–48.63%
Yellow-billed Duck	S	810.6	497.4	327.7	–38.64%	–34.12%	–59.58%
	W	610.3	655.2	181.8	7.37%	–72.25%	–70.20%
Great White Pelican	S	5.6	9.0	49.0	60.98%	444.44%	776.42%
	W	17.5	12.7	44.9	–27.59%	254.24%	156.49%
Greater Flamingo	S	311.5	52.8	12.7	–83.05%	–76.01%	–95.93%
	W	192.8	7.1	48.0	–96.31%	576.26%	–75.08%
Lesser Flamingo	S	48.5	1.1	0.3	–97.83%	–68.25%	–99.31%
	W	177.5	1.8	22.0	–98.98%	1111.44%	–87.63%
All waterbirds	S	8203	6104	4370	–25.59%	–28.41%	–46.73%
	W	6998.2	5443.1	3646.5	–22.22%	–33.01%	–47.89%

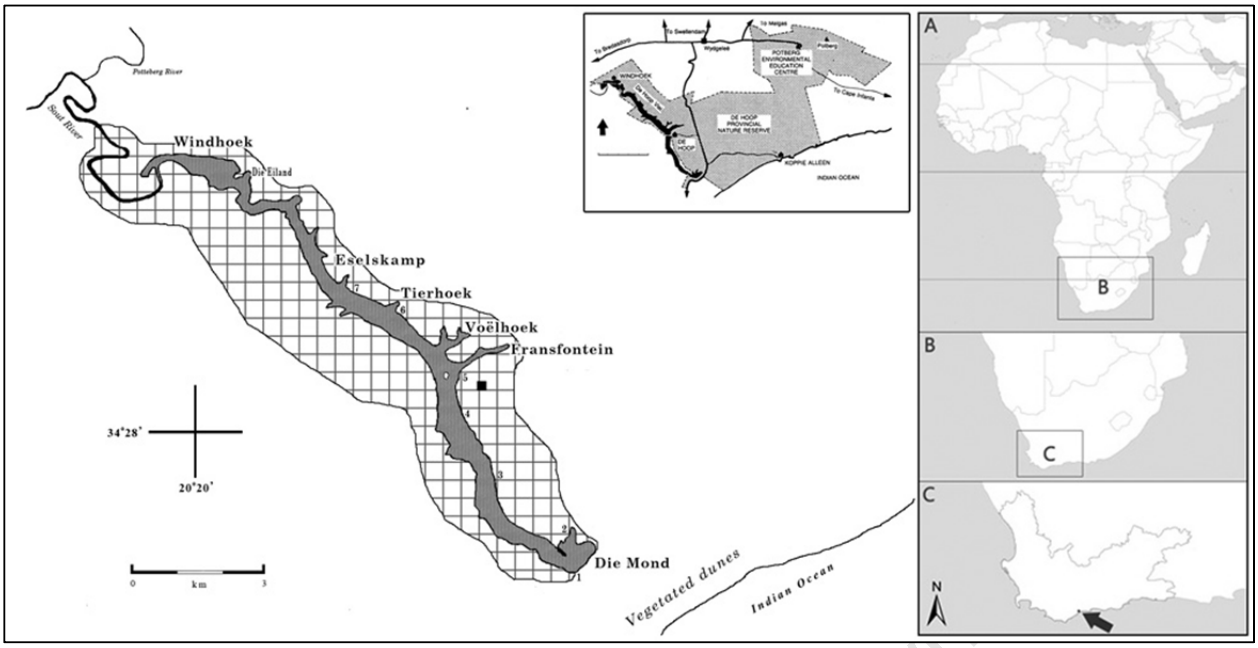

Figure D.1 Map of De Hoop Vlei showing the location of the De Hoop farmstead (now the nature reserve offices), some of the major bays and the points (1–7) at which surveys were undertaken. The hatched area represents the milkwood dominated riverine bush (modified from Uys and Macleod 1967, Coetzee 1986). Inset shows the location of the lake in relation to De Hoop Nature Reserve. Map sourced from Uys (1983).

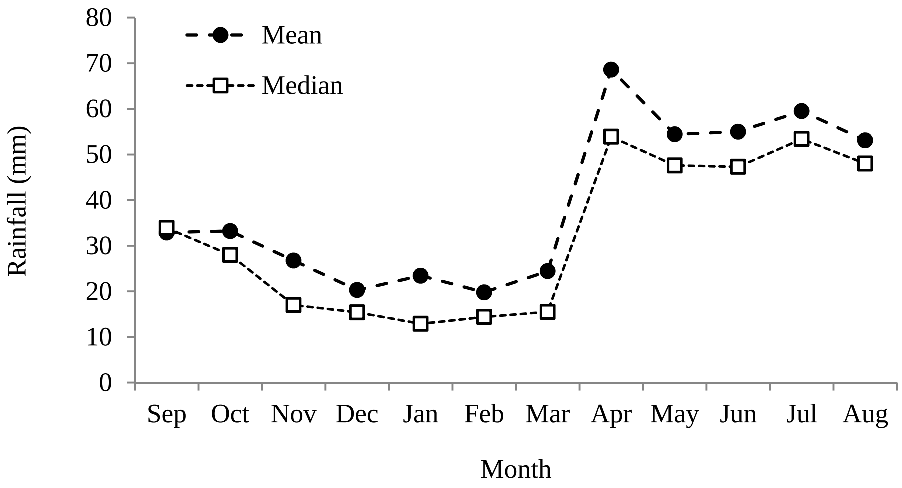

Figure D.2 Mean and median monthly rainfall from the Cape Agulhas region from 1980–2009. Figures based on data from De Mond rainfall station.

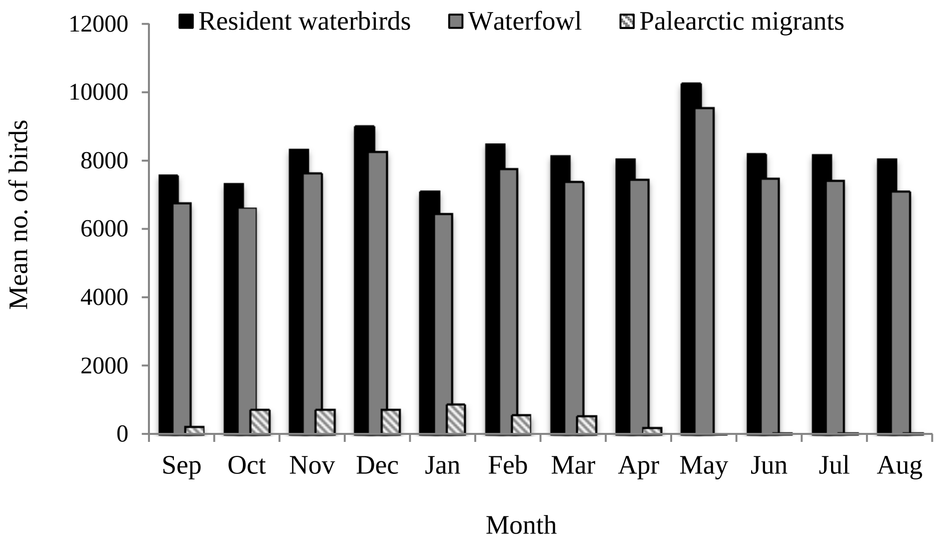

Figure D.3 Mean monthly abundance of all waterbirds at De Hoop Vlei from 1979–2004. Data is separated into resident species, Palearctic migrants and waterfowl to show relative contributions to monthly abundance.

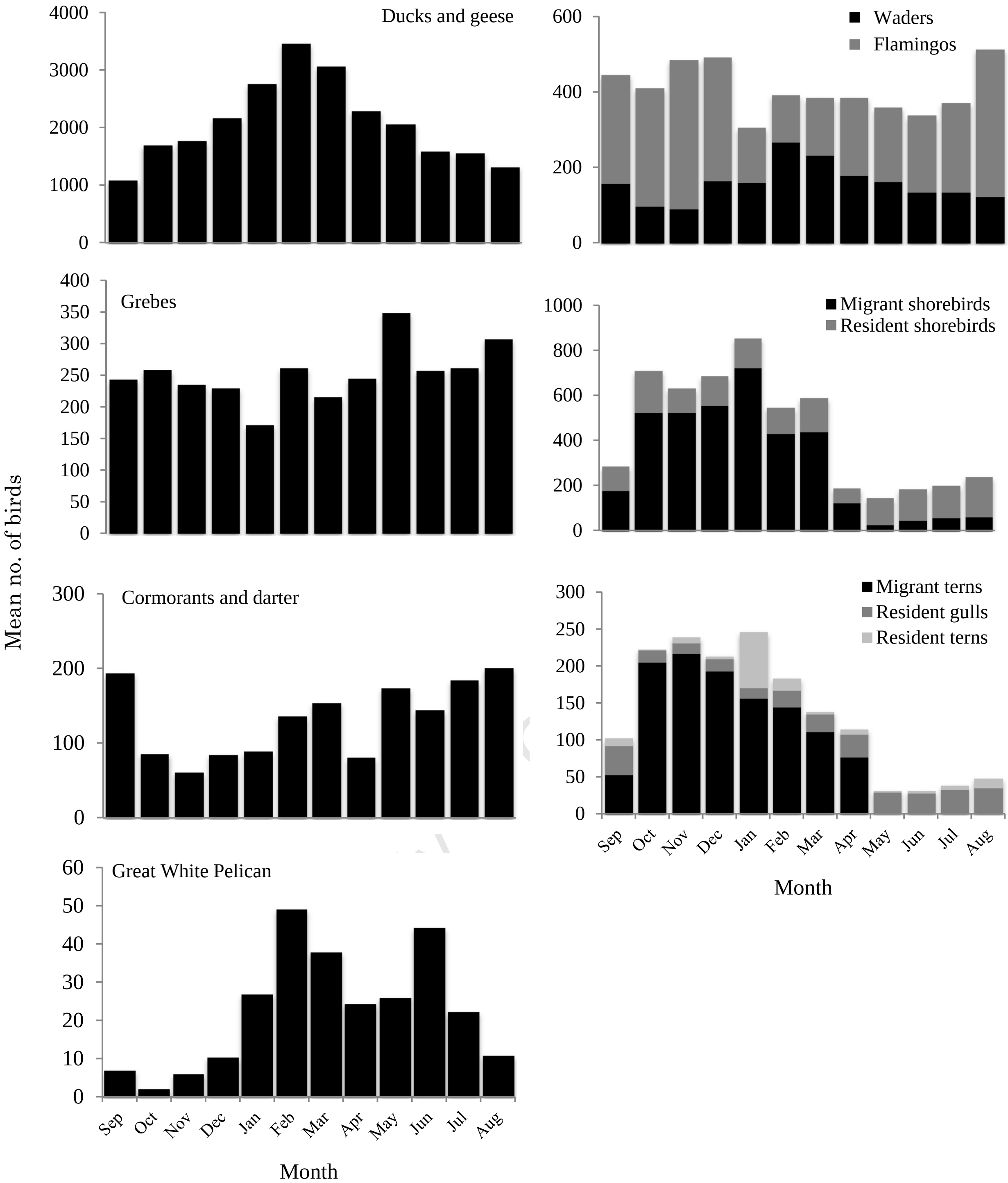

Figure D.4 Mean monthly abundance of eleven waterbird guilds at De Hoop Vlei from 1979–2004. Waterfowl have been separated into ducks and geese, and grebes to show individual patterns.

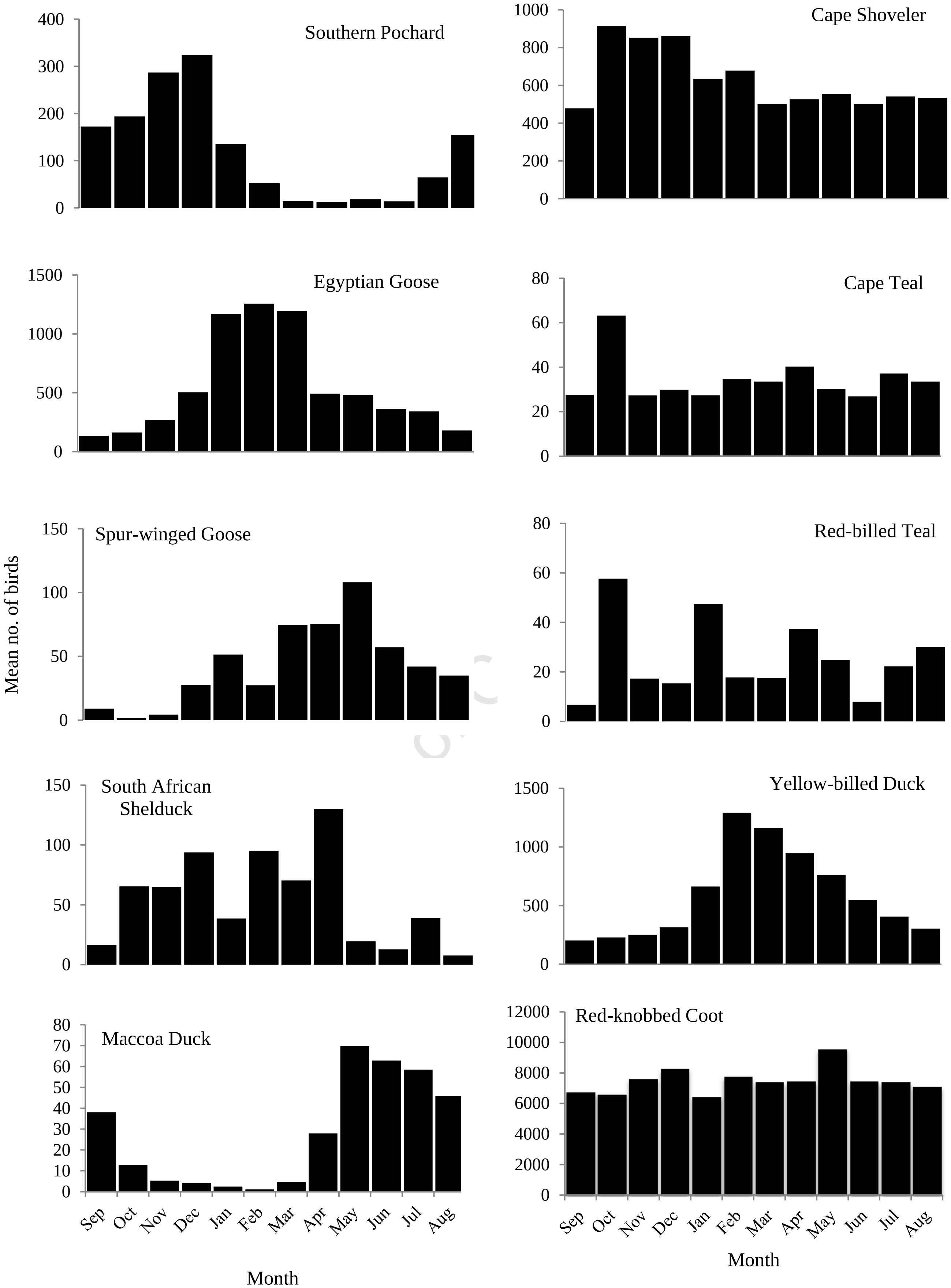

Figure D.5 Mean monthly abundance of 10 waterfowl species at De Hoop Vlei from 1979–2004.

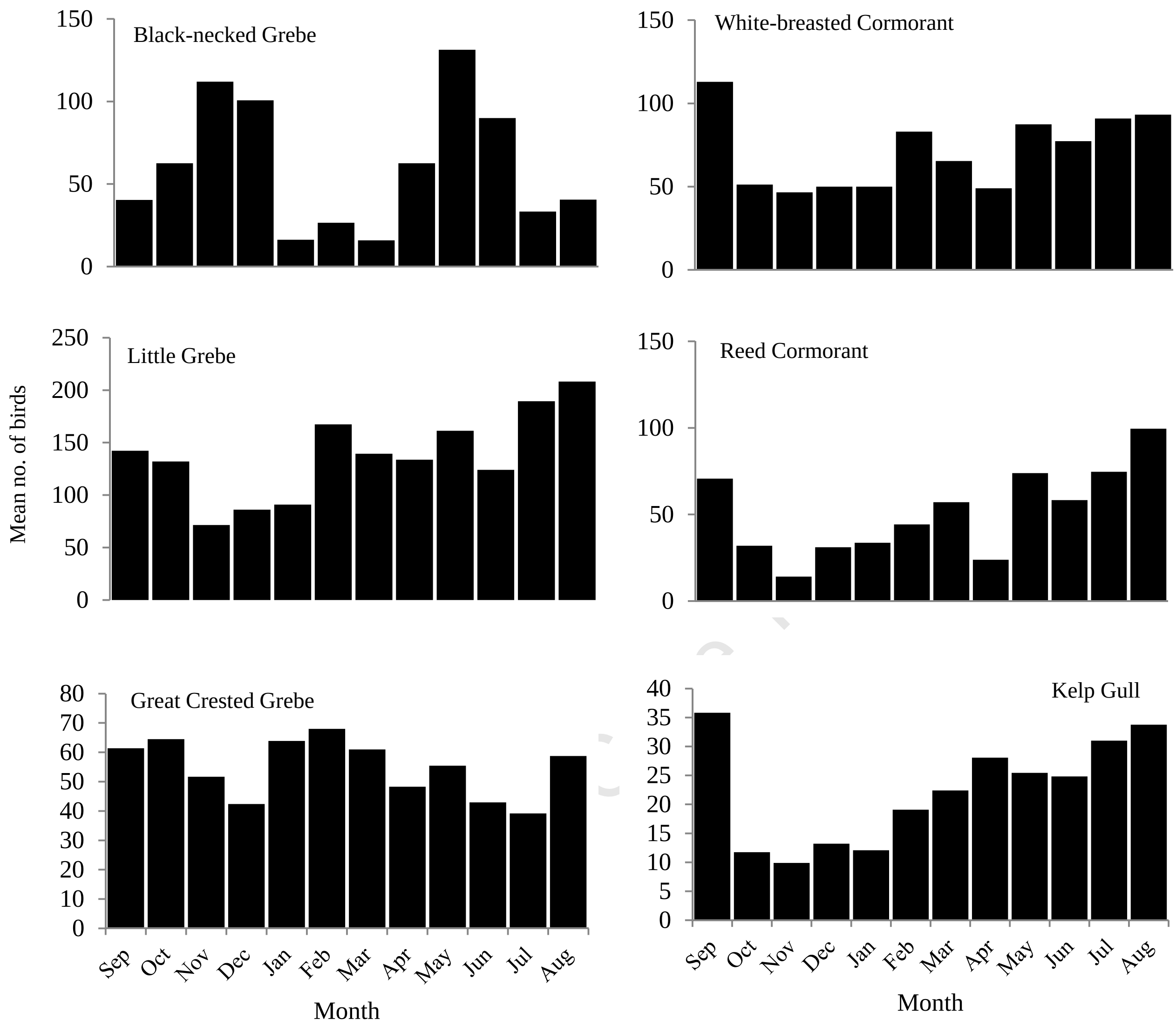

Figure D.6 Mean monthly abundance of three grebe species, two cormorant species and Kelp Gull at De Hoop Vlei from 1979–2004.

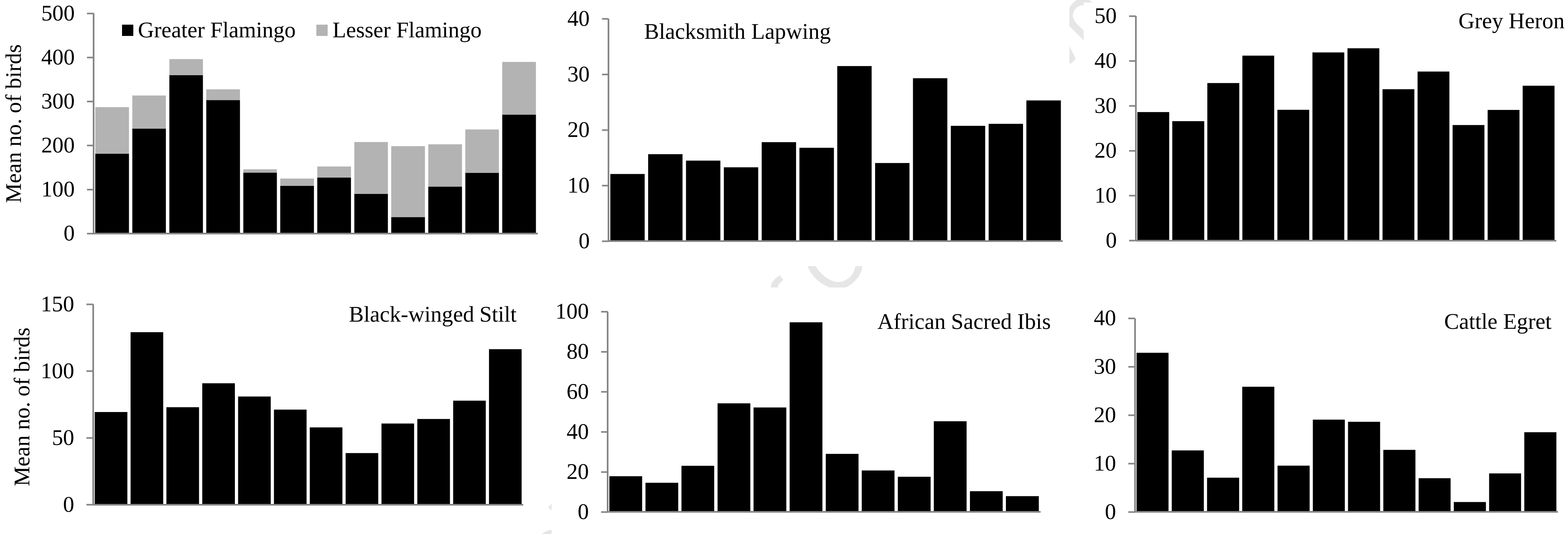

Figure D.7 Mean monthly abundance of selected resident shorebirds and waders at De Hoop Vlei from 1979–2004.

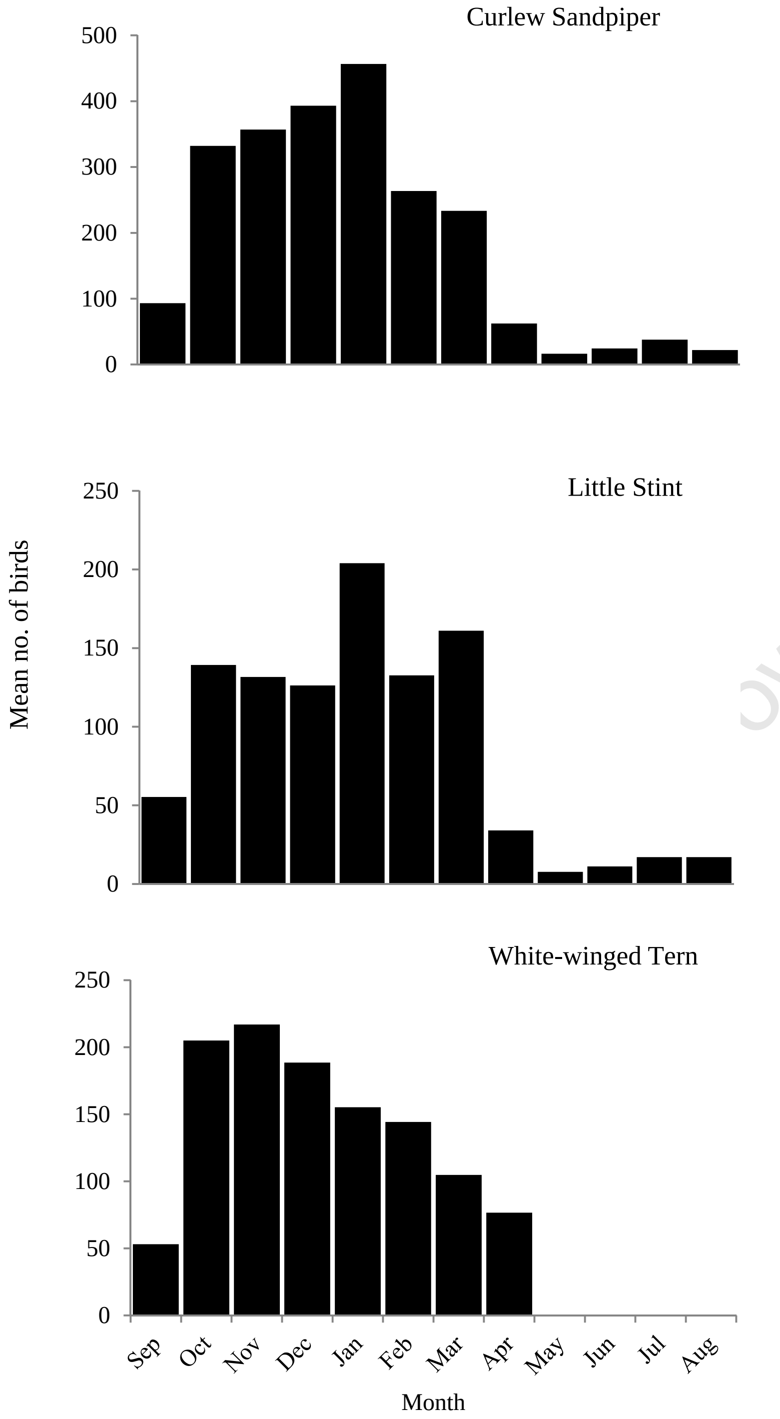

Figure D.8 Mean monthly abundance of selected Palearctic migrant waterbirds at De Hoop Vlei from 1979–2004.

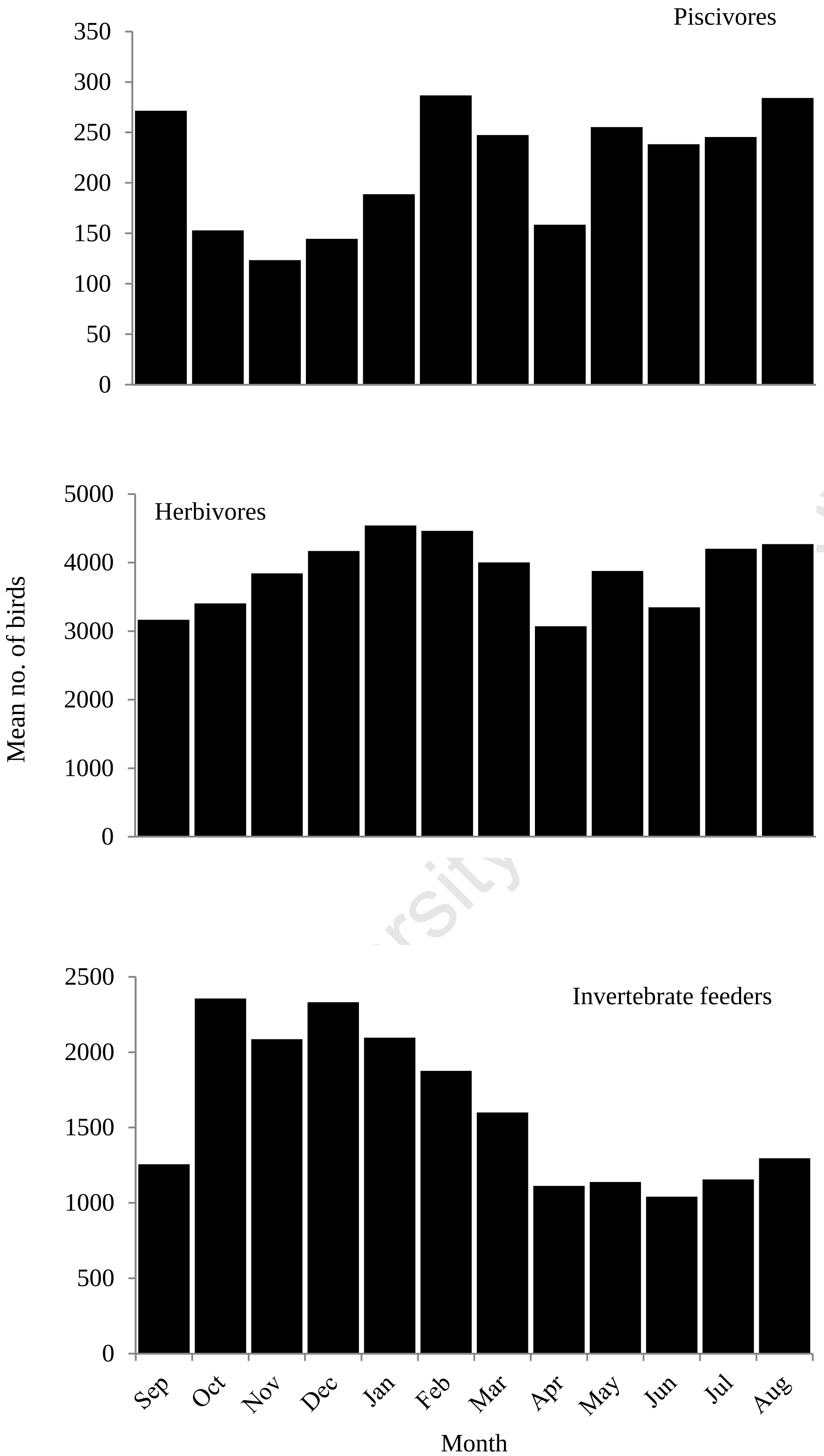

Figure D.9 Mean monthly abundance of piscivorous, herbivorous and invertebrate feeding waterbirds at De Hoop Vlei from 1979–2004.

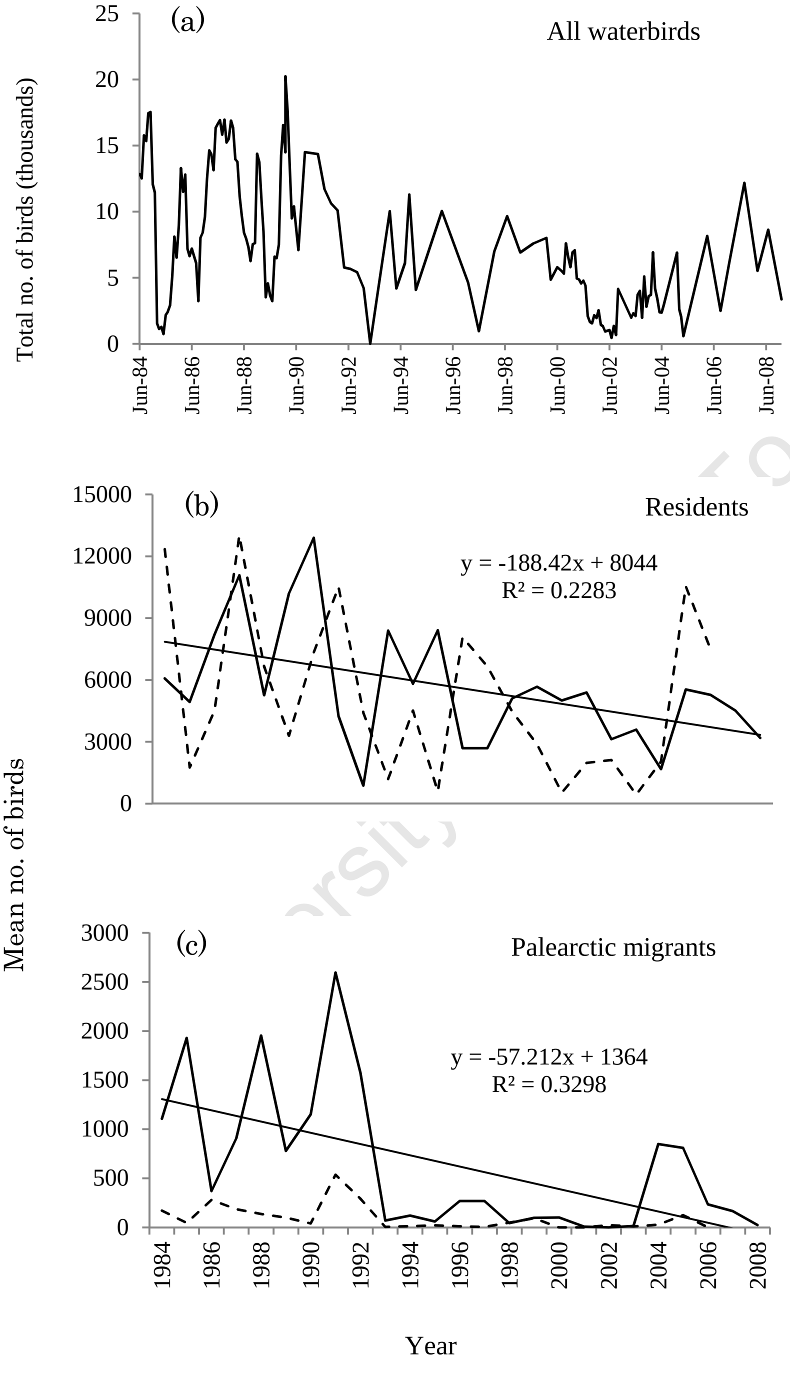

Figure D.10 (a) Total no of waterbirds counted at De Hoop Vlei from 1984–2008. Summer (solid line) and winter (dashed line) inter-annual variation and trends in mean abundance of (b) resident and (c) Palearctic migrant waterbirds at De Hoop Vlei from 1984–2008. Regression lines are shown for summer where appropriate.

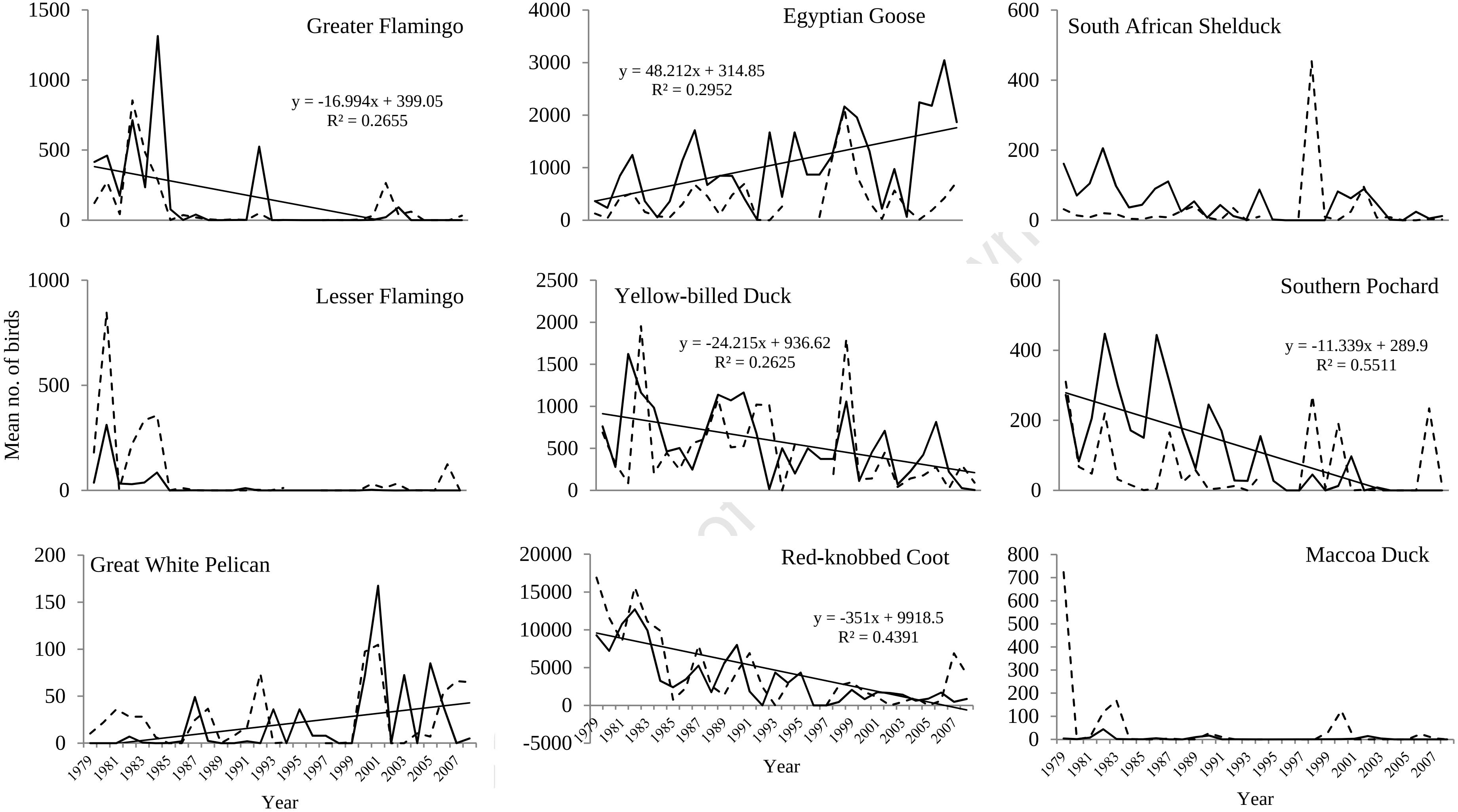

Figure D.11 Inter-annual variation and trends in mean abundance of flamingos, pelicans and waterfowl at De Hoop Vlei from 1979–2008. Solid lines =summer, dashed line = winter. Regression lines are shown for summer where appropriate.

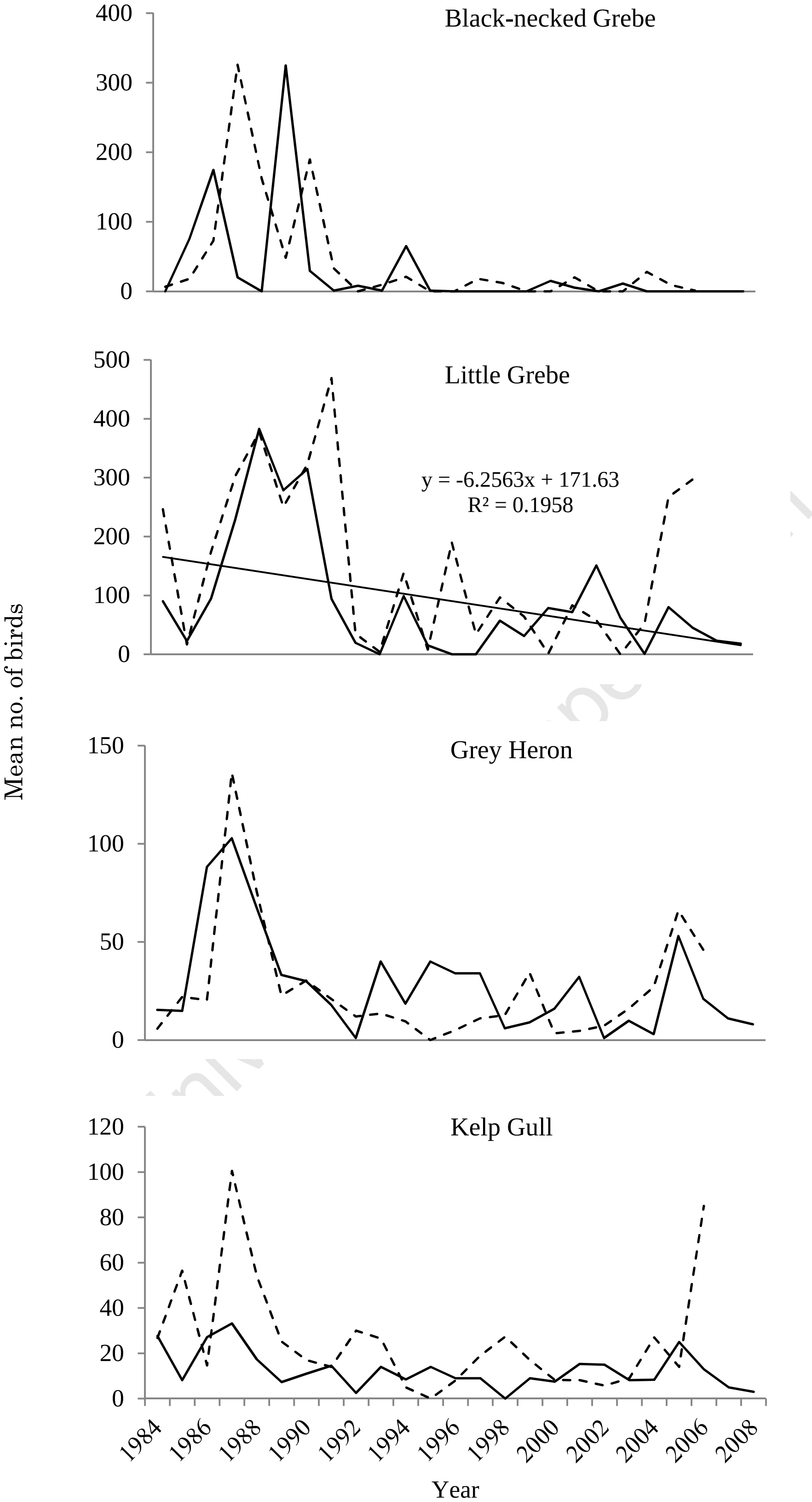

Figure D.12 Inter-annual variation in mean abundance of four resident waterbirds at De Hoop Vlei from 1984–2008. Regression lines are shown for summer where appropriate.

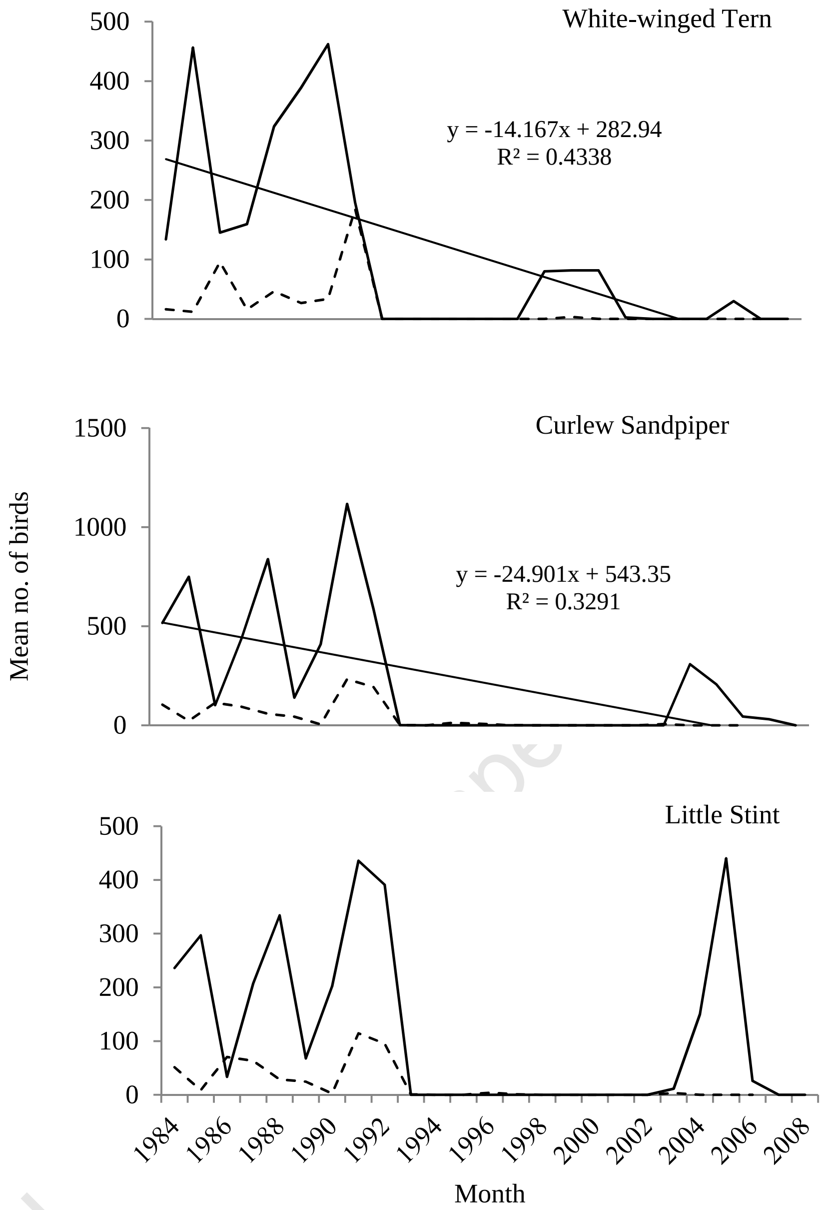

Figure D.13 Inter-annual variation in mean abundance of three Palearctic migrant waterbirds at De Hoop Vlei from 1984–2008. Regression lines are shown for summer where appropriate.

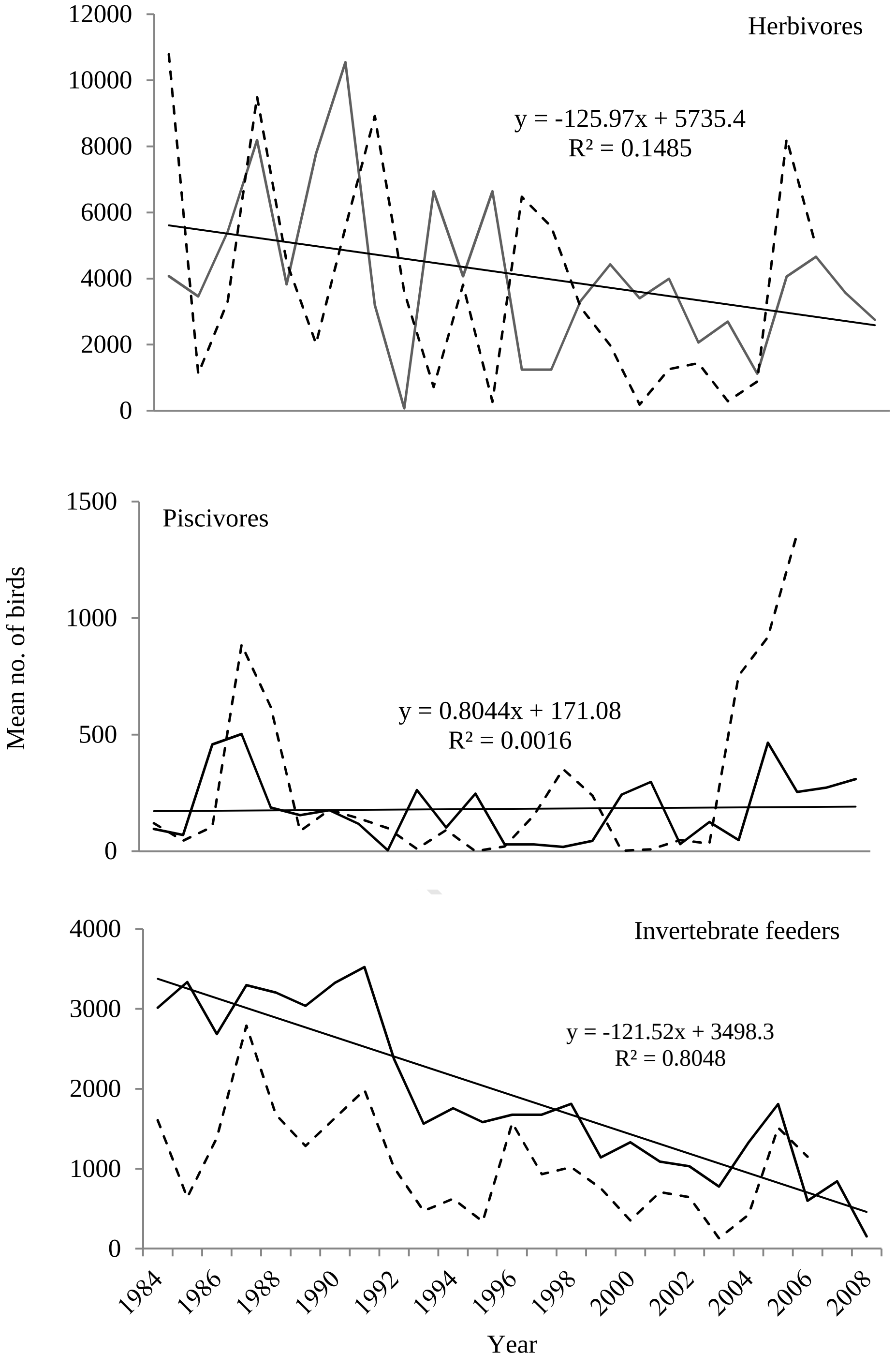

Figure D.14 Inter-annual variation in mean abundance of three major waterbird feeding guilds at De Hoop Vlei from 1984–2008. Regression lines are shown for summer.

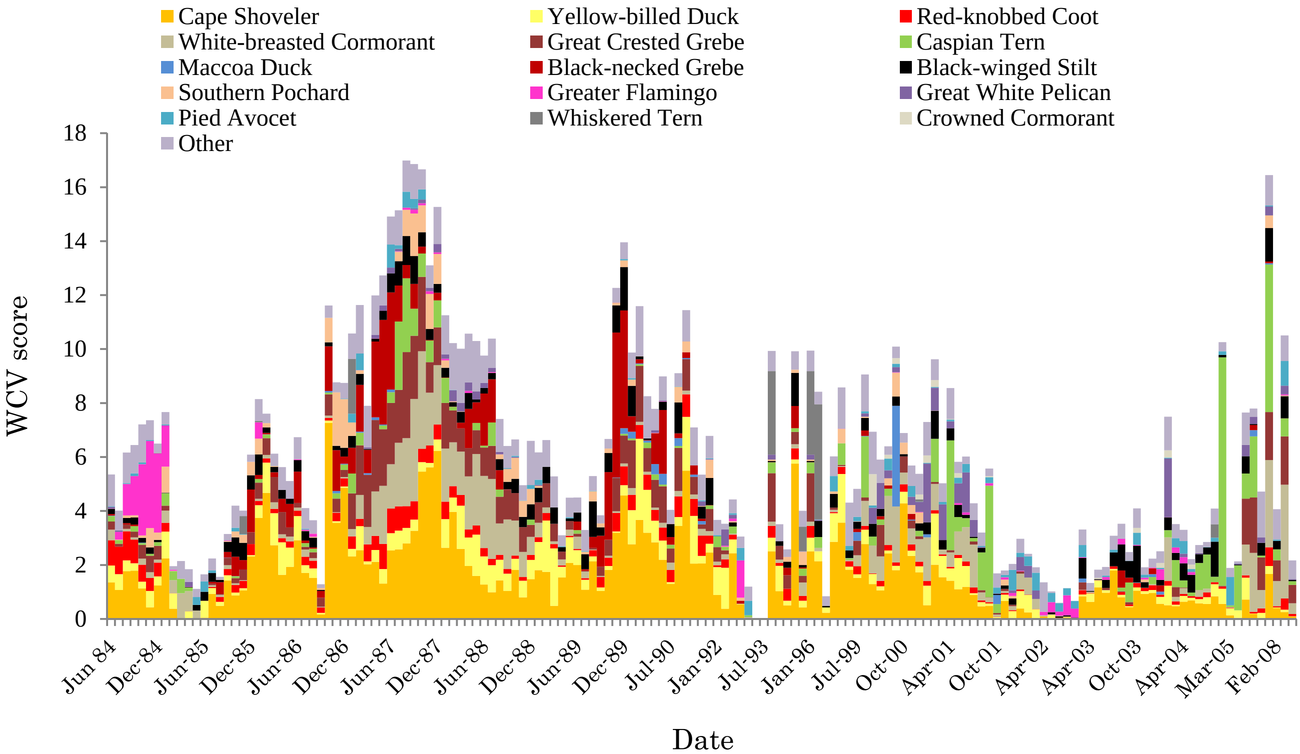

Figure D.15 Monthly Waterbird Conservation Value (WCV) scores for De Hoop Vlei from June 1984–January 2009. Relative contributions of species reaching 0.5% or 1%

threshold levels are shown.

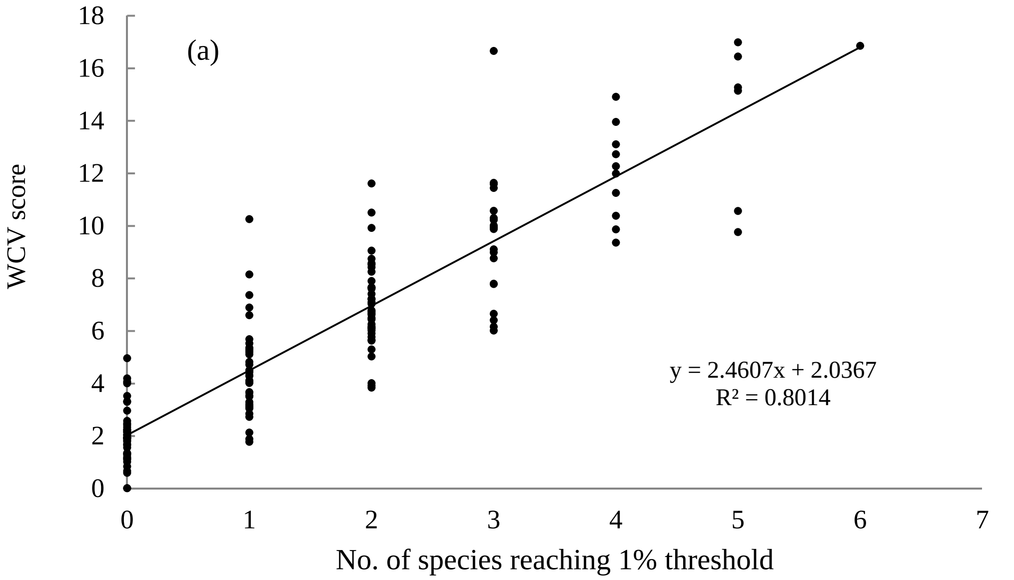

Figure D.16 The relationship between (a) the Waterbird Conservation Value (WCV) score and the number of species reaching their 1% levels and (b) the WCV score and the total count of waterbirds at De Hoop Vlei. Both plots cover all surveys from July 1984–January 2009 (n = 201).