Ecological impacts of biological invasions on native birds in Africa.

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Abstract

The impacts of biological invasions on native avian diversity have been the subject of many studies in Africa. However, a holistic synthesis of available information from different taxa and their impacts on native birds is lacking. From published information, I analysed the negative and positive effects of biological invaders on native African birds from five taxa: plants, invertebrates, fish, mammals and birds. In order to assess functional gains and losses, native birds were categorized into their functional guilds defined by their primary diet. I limited my scope to mainland Africa at the biome level. ArcView GIS 3.3 software was used to map locational data of impacts within the major biomes. The results indicate that a minimum of 572 native birds are negatively impacted by invasive species from the five taxa. This represents *ca* 29% of all the bird species in Africa. In contrast, only 191 species of native birds benefited from such invasions. Birds whose diet was primarily insects were disproportionally impacted. The majority of the impacts were caused by invasive plants. At the biome level, the greatest numbers of native birds impacted were in the Montane grassland and shrubland biome. It is predicted that native birds will continue to lose more than they gain from biological invasions in the continent.

Key words: Invasive, impacts, native birds, biodiversity, biomes, Africa.

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CHAPTER 1: INTRODUCTION

Introduction of exotic species and biological invasions

Biological invasions threaten the ecological integrity of the world's ecosystems and its biodiversity (Levin et al. 2003), altering energy flows and the physical structure of ecosystems (e.g. Crooks 2002). Mostly through human mediation, biological invaders are spreading in all geographical regions and their detrimental impacts on the world's biodiversity and economy are increasing in severity (Schmitz & Simberloff 1997; Vitousek et al. 1997). Some of the resultant ecological consequences and changes, such as species' extinctions, are irreversible (Norton 2009). Birds are particularly sensitive to structural changes in their habitats and can alter their ranges rapidly in response to such changes (e.g. Hockey 2003), making them potentially valuable indicator taxa.

Invasive species can be categorised in two ways. The first category comprises native species that expand their ranges and have ecological impacts in the new habitats/areas that they colonise. The second category comprises non-native species that have been introduced either deliberately or accidentally outside their native ranges and have subsequently become invasive. In this study, an invasive species is defined as being a self-sustaining population of introduced, non-native species that become established outside their native range (Richardson et al. 2000a). Such invasive species may have detrimental ecological and economic consequences for invaded species, communities, or ecosystems.

An introduced species may become naturalized after introduction (incorporated into the resident taxa), and its offspring may thereafter become invasive

by overcoming survival and reproductive barriers (Richardson et al. 2000a). However, the condition in the definition that the offspring of an introduced invasive species should naturally spread away from the site of introduction may exclude some species whose distribution or movement is controlled by man. For example, in some studies, naturalized species like some species of domestic livestock are not considered to be invasive because they are controlled by man (e.g. Gurevitch & Padilla 2004), yet they can have widespread impacts on biodiversity through overgrazing (e.g. Muchai 2002). Moreover, many studies report high livestock densities leading to overgrazing, and as such they may be considered to have overcome survival and reproductive barriers. In this case, man is the agent that facilitates 'invasion' into natural areas by livestock, with the resultant potential for overgrazing. In addition, lack of acknowledgement of such species as being invasive may also probably stem from the long time that has elapsed since introduction whereby they are considered part of the resident biota (naturalized).

Some of these arguments may hold true for some introduced plants. For example, some introduced plantation plants in South Africa have spread beyond the plantations into natural areas and are therefore correctly considered to be invasive (e.g. Richarson et al. 1994). In contrast, the distribution of many agricultural crops is tightly controlled by man and hardly spread beyond the farmed areas into natural areas. They are therefore rightly considered to be non-invasive. Based on these arguments, I suggest that the definition of an introduced invasive species is deficient in addressing impacts of 'farmed' species and should be revised accordingly to accomondate those specific cases. For this study, I therefore consider introduced livestock species and some plantation plants as being invasive in Africa.

Negative impacts of invasive species on native birds

The ecological costs of biological invasions are often quantified in terms of biodiversity loss. Multiple ecological impacts of invasive species on native bird species and assemblages have been documented. These include effects on individuals, population genetics and dynamics, and community and ecosystem processes (Parker et al. 1999; van Wilgen et al. 2001). Some studies have proposed that invasions are homogenizing the world's biota (Lockwood et al. 2000; Blair 2001; Collins et al. 2002; McKinney 2006) by changing the structure and ecological functioning of the invaded communities (Crooks 2002; Levin et al. 2003). Thus, in many invaded communities, native species are replaced by a few invasive species to the point where biological invasions are widely recognized as a primary cause of global biodiversity loss, second only to habitat loss (Vitousek et al. 1997).

Invasive plants, invertebrates, fish, mammals, and other birds all impact on native birds and have affected *ca* 30% of globally threatened bird species (BirdLife International 2008).

Impacts of invasive plants on native birds

Studies of invasive plants have documented their negative impacts on both native vegetation and bird communities. Some invasive plants restructure the native vegetation by forming monotypic stands such as the mesquites (*Prosopsis* spp). which have invaded rangelands in East and South Africa and replaced most of the indigenous plants (Pasiecznik 1999; Richardson & van Wilgen 2004). Mesquite has invaded large areas of the Baringo district of Kenya, and continues to spread into other African countries (Mwangi & Swallow 2005). The nature and extent of such

invasions by *Prosopsis* spp. are expected to affect bird communities in the invaded areas (Richardson & van Wilgen 2004). For example, in the arid Kalahari, areas invaded by *Prosopsis* sp. have fewer understorey plants compared to uninvaded areas and a lower diversity and species richness of native birds in the area was attributed to the invasion by *Prosopsis*: most noticeable was the total absence of raptors in the *Prosopis*-invaded area (Dean et al. 2002). Anderson (2000a) suggested that due to formation of dense stands, *Prosopsis* spp. could negatively affect raptors through reduction of their prey base in the Northern Cape, South Africa.

The diet of native birds may be altered by invasive plants. Where invasives replace native food plants, birds may need to adjust before they switch to the new food resource (Kruger et al. 1986). An example of altered diet was reported by Oatley (1984) in KwaZulu-Natal, South Africa, where the diet of African Olive-Pigeons (*Columba arquatrix*) comprised a high percentage of the alien invasive Wild Tobacco Bush (*Solanum mauritianum*). It has also been suggested that invasive plants can be particularly threatening to specialist foragers. For example, Protea Seedeaters (*Crithagra leucopterus*), which are dependent on the seeds of *Protea neriifolia* and *P. cliffortia* as food, are at risk due to invasion by *Acacia* and *Hakea* spp. in southwestern Cape, South Africa (Siegfried 1973). Invasive species may thus disrupt bird-plant mutualisms (Traveset & Richardson 2006).

Impacts of invasive invertebrates on native birds

The impacts of invasive invertebrates on native birds depend on their ecological roles and may be direct or indirect (Kenis et al. 2009). Invasive predatory invertebrates may, for example, prey on chicks or adult birds in their nests causing mortality, breeding failure and population decline (e.g. Holway et al. 2002; Allen et al. 2004;

Suarez et al. 2005). Allen et al. (2004) for example, reviewed the negative impacts of the highly invasive Red Imported Fire Ant (*Solenopsis invicta*) and proposed that the ants were depredating and subsequently causing population decreases of several species of native birds in the USA. Indirect interactions between invasive invertebrates and native birds from disruption of processes like pollination or seed dispersal has also been documented (e.g. Traveset & Richardson 2006).

At least five of the most damaging invasive ants have been introduced into Africa (Holway et al. 2002) where they may be causing substantial ecological damage. One of these, the Argentine Ant (*Linepithema humile*), has been the subject of several studies in Africa (e.g. Buys 1987; Matilya 2003; Lach 2007, 2008; Raharinjanahary 2007) where it has displaced native ants. Most of these studies have concentrated on displacement of native ants but there is a scarcity of information on their effects on native birds. However, there is a possibility that these displacements indirectly affect other taxa, including native birds (Holway et al. 2002).

Another possible consequence of invasive invertebrates on native birds is transmission of parasites and pathogens. Birds are both biological carriers and hosts of many parasites and pathogens (Hubálek 2004). These parasites and pathogens may have different impacts on birds. Effects of pathogenic and parasitic infections on native birds include disease, reduced reproductive success, mortality, or even extinctions (Cooper 1989). Experimental studies have shown that parasitic infections reduce fecundity and survival of wildlife, including birds (Tompkins & Begon 1999). In Hawaii, for example, several endemic birds have undergone population reductions of up to 90% (Blackburn et al. 2009) or gone extinct as a result of the introductions of

the invasive mosquito (*Culex quinquefasciatus*) in 1826 (Van Riper et al. 1986) and avian pox (*Poxvirus avium*) in the 1800s (Alicata 1964).

Impacts of invasive fish

Introductions of alien fish have been implicated in declines of native fish populations (e.g. see Bruton & van As 1986; Goudswaard & Wanink 1993; Pitcher 1995; Goudswaard et al. 2008). Pitcher (1995) proposed that the effects of established, alien fish in different ecosystems would depend on their functional roles – whether they are piscivores, planktivores or herbivores. For example, the predatory Nile Perch (*Lates niloticus*) in Lake Victoria, East Africa, has been implicated in the extinction of at least 200 native species of cichlid fishes (Goudswaard & Wanink 1993; Kudhongania & Chitamwebwa 1995; Goudswaard et al. 2008). The Lake is now dominated by only three species: Nile Perch, Nile Tilapia (*Oreochromis niloticus*) and Silver Cyprinid (*Rastrineobola argentea*) (Kudhongania & Chitamwebwa 1995). In response to such dramatic changes in fish abundance and diversity, some piscivorous birds have been deprived of their normal food source and have subsequently changed their diet (Goudswaard & Wanink 1993). For example, Great Cormorants (*Phalacrocorax carbo*), which previously depended on haplochromines, have changed their diet to the more available, introduced *R. argentea*. The study also showed that *R. argentea* is a poor-quality food source, implying that diet change as a result of invasive species may not always benefit native birds in terms of food quality. However, studies of such direct and negative ecological effects of invasive fish species on native birds in Africa are few.

Impacts of invasive mammals

Globally, introductions of predatory mammals have been implicated in population reductions, and in some cases extinction, of native birds. For example, the majority of invasive species that affect globally threatened birds are invasive mammalian predators (BirdLife International 2008).

Depredation of native birds, especially insular taxa, by introduced predators is particularly damaging because in many cases the native birds have evolved without predators (Blackburn et al. 2004). Indeed, this is one of the reasons why introduced mammalian predators have had such devastating effects on oceanic island birds. For example, on Ascension Island, both rats (*Rattus rattus*) and Common Mynas (*Acridotheres tristis*) prey on the eggs and chicks of Sooty Terns (*Sterna fuscata*), causing breeding failure and leading to a population decrease (Blackburn et al. 2009). At Gough and Inaccessible Islands, the Tristan Albatross (*Diomedea dabbenena*) is threatened by introduced House Mice (*Mus musculus*) (Wanless et al. 2007). Introduced cats have also been implicated in the extinction of at least six island-endemic birds, including the Stephen Island Wren (*Xenicus lyalli*) in New Zealand (Hockey 2001; Clout 2002).

Impacts of invasive birds

Invasive birds impact native birds in several ways. These include competition, predation and even extinctions (e.g. Birkhead 1988; Ryall 1992; Sodhi et al. 2005; BirdLife International 2008; Blackburn et al. 2009; Freed & Cann 2009). Most of these studies have reported native birds as the losers in these interspecific interactions.

Direct competition for various resources including nest sites and food between invasive and native birds has been implicated in the decline of native species. Competition for food to the disadvantage of native birds can be serious if it impairs their growth and survival (e.g. Freed & Cann 2009). This effect has been documented for passerine birds in Hawaii (Freed & Cann 2009). For example, the introduced Japanese White-eye (*Zosterops japonicus*) competes for food with native species, including the *Endangered* Hawaii Akepa (*Loxops coccineus*), resulting in reduced growth rates and, ultimately, poor survival of the native birds. The Japanese White-eyes do not experience the same negative effects, suggesting that the competition is strongly asymmetric.

There are few studies in Africa that have investigated similar impacts. However, studies have reported competition for food and nest sites between the native and invasive species. One example is the alien American Ruddy Duck (*Oxyura jamaicensis*) which competes for food and nest sites with native White-headed Duck (*O. leucocephala*) in several north African countries including Algeria, Morocco, Tunisia and Egypt (Collar et al. 1994; CMS Technical Series 2006; Banks et al. 2008).

Competition for nest sites between invasive and native birds, especially cavity nesters that do not excavate their own nest holes, can be very disruptive (Blackburn et al. 2009). One consequence of this interaction may be reduction in the breeding success of native birds. For example, in the USA, Common Starlings (*Sturnus vulgaris*) aggressively oust native cavity-nesting birds, leading to decreases in the numbers of native cavity nesters (Blackburn et al. 2009). In Mauritius, the endemic Echo Parakeet (*Psittacula eques*) is *Endangered* because it has a small, highly range-

restricted population and its habitat is being rapidly degraded, primarily through invasion by alien plants (BirdLife International 2008). This problem is exacerbated by Rose-ringed Parakeets (*Psittacula krameri*) and Common Mynas, which compete for nest sites with Echo Parakeets (Jones 1980). In southern Africa, displacement of native hole nesters by Common Starlings has been reported with resultant reduction in nesting success, but there is no evidence of population decreases as a result (van der Merwe 1984). Similarly, Common Mynas have displaced hole nesters like the Green Wood-Hoopoes (*Phoeniculus purpureus*) from their nests in Johannesburg, South Africa (Birkhead 1988).

Some invasive bird species are predators of native birds, and this can lead to population decreases. For example, Blackburn et al. (2009) report nest failure and population decrease of Tahiti Flycatchers (*Pomarea nigra*) due to predation by Common Mynas. Common Mynas are also nest predators of the *Critically Endangered* St Helena Plover (*Charadrius sanctaehelenae*) (BirdLife International 2009a). In eastern Africa, the House Crow (*Corvus splendens*) has been a key predator of several bird species, resulting in significant changes to some local bird communities (Ryall & Reid 1987; Ryall 1992; Archer 2001).

Extinctions of species represent irreversible biological losses. Extinction of birds, especially on oceanic islands, is relatively well documented. In a review of bird extinctions on African islands, Hockey (2001) reports that between the year 1600 and 2000, approximately 136 species of birds have become extinct globally. Of these extinctions, *ca* 124 occurred on islands. African islands lost approximately 35 species, with the majority being in the Mascarenes (30 species). Overall, Africa's islands have lost more than half of their native species since 1600. Many of the affected birds are

island endemics (Hockey 2001; Lengyel 2001). There are no known extinctions of native birds in mainland Africa over the same time period (Hockey 2009a).

Although the causes of these extinctions are varied, in many cases invasive species are heavily implicated. For example, of the 129 species of birds that have gone extinct since 1500, invasive species were implicated in the extinction of at least 71 (BirdLife International 2008).

Benefits of biological invasions to native birds

Some invasive species are beneficial to native birds. Invasive plants, for example, may provide food, nesting and roosting sites, and cover required by birds (e.g. Smith 1974; Glyphis et al. 1981; Boshoff et al. 1983; Allan et al. 1997; Anderson 2000a; Malan & Robinson 2001). For example, Dean and Milton (2000) observed Cape Crows (*Corvus capensis*) feeding, perching and nesting on *Opuntia* sp., as a result of which the distribution and abundance of the crows increased.

The (intentional) introduction of the alien Nile Perch into Lake Victoria has benefited the African Fish-Eagle (*Haliaeetus vocifer*) by providing an additional food source (Goudswaard & Wanink 1993). Similarly, the African Black Oystercatcher (*Haematopus moquini*) has benefited from the (unintentional) introduction and subsequent invasion of the Mediterranean Mussel (*Mytilus galloprovincialis*) along the southern African coast (Hockey & Schurink 1992; Coleman & Hockey 2008; Hockey 2009b).

Impacted ecosystems and biomes

Many biological invaders and their effects on natural ecosystems and biomes in mainland Africa have been documented, especially in southern Africa. These areas differ on the degree of invasion by various species. Subsequently, the impacts on native birds from biological invasions in these same ecosystems and biomes are variable. For example, the Fynbos biome in South Africa is a biodiversity hotspot (Conservation International 2007) and is heavily invaded by plants which have affected the composition of biome's bird communities (e.g. Middlemiss 1963; Macdonald 1986; Hockey et al. 1989; Fraser 1990a). However, most African countries have not quantified or mapped the spatial extent of biological invasions. An exception is South Africa which has made remarkable progress in this respect. For example, Richardson and van Wilgen (2004) report that over 10 million hectares in South Africa are invaded by approximately 180 plant species across all biomes. The extent of such invasions can be predicted to precipitate major negative consequences for biodiversity.

Aims of this study

This study aims to collate and synthesize published information on the impacts of biological invasions on native birds in mainland Africa. The specific aims are:

i) to assess the ecological impacts and contribution of invasive plants, invertebrates, fish, mammals, and other birds on native birds;

ii) to identify response patterns of different feeding guilds of birds to the impacts; and

iii) to identify the patterns of impacts at the biome level.

Based on these objectives, there are several possible lessons to be learnt from the study. Firstly, the assessment will enable us to know the magnitude of the problem in terms of losses and gains to native birds from biological invasions. Secondly, appreciation of the extent of the problem is important to conservation practitioners in prioritising conservation actions. Finally the study identifies gaps in knowledge that should form priorities for future research efforts.

CHAPTER 2: METHODS

I conducted a literature search of published studies on the impacts of invasive species on native terrestrial and coastal birds in mainland Africa. The scope was limited to the biome level.

Information as to whether a species was invasive or not was obtained primarily from the IUCN Global Invasive Species Database (http://www.issg.org/database/species/). However, because many countries may not have updated their records in the database, I also considered published information sufficient for inclusion in the database. Information on studies conducted in Africa was sourced from different publications, including the Afrotropical Bird Database (http://web.ebscohost.com/ehost).

The invasive species covered in this review were from five taxa: plants, invertebrates, fish, mammals and birds.

Information that was collected and recorded included the invasive species affecting the native bird(s), species of native bird(s) affected and reported impact and type (whether positive or negative).

Birds were classified into feeding guilds based on their primary diets. Data were obtained from diverse publications including Hockey et al. (2005) and del Hoyo et al. (1990-2008). Birds were classified into one of eight feeding guilds: carnivore, herbivore insectivore/invertebrate feeder, frugivore, granivore, nectarivore, piscivore or omnivore. Data were also collated on the country or region where the impact(s) occurred.

I analyzed the reported negative impacts of invasive plants on native birds from several studies in Africa. The invasive plants included in the analysis are those that are planted but known to be invasive as well as non-planted invasive plants. I grouped the reported negative impacts into two categories: habitat loss and lowered food availability.

Native birds impacted by habitat loss include those which avoid areas invaded by alien plants, and those that were reported to have lost roosting, breeding or foraging sites. It also included those whose abundance was higher in indigenous than invaded habitats. Birds which were present in the invaded areas or made infrequent visits but did not utilize any resources therein were in this category. The category also included habitat loss reported as an effect on its own.

Loss of food from the invasive plants was widely reported hence the category – reduced food availability. This includes birds whose diet was reported to change from the invasions. Disruption of feeding behaviour was mostly inferred (e.g. Oatley 1984) because the subject was inadequately investigated and under-reported.

All positive impacts reported from invasive plants on native birds were grouped into two categories: habitat suitability and food availability.

In addition to other invasive invertebrates reported, data collected also included parasites and pathogens that have both positive and negative effects on native birds. These parasites and pathogens include those that were deliberately or accidentally introduced in the continent. Data on the highly pathogenic Avian Influenza virus outbreaks in the continent were excluded because there is no firm evidence of invasivity (Boyce et al. 2009).

Data on the negative impacts of invasive fish on native birds was grouped into three categories: habitat loss, altered diet (including altered feeding behaviour), and competition for food. All reported positive impacts were linked to increased food availability.

The negative impacts of invasive mammals were grouped into three main categories: reduced food availability (including competition), predation, and general habitat loss (including loss of breeding and or nesting sites). Habitat suitability was the only type of positive impact from invasive mammals.

I grouped all reported negative impacts from invasive birds into four main categories: predation, hybridization, aggression and displacement, and competition. The total number of birds affected by each impact was then tallied.

To assess and compare gross impacts from all taxa**,** the total number of bird species affected by invasive species from each of the five taxa was tallied. The same was done for the feeding guilds.

I mapped the spatial distribution of negative impacts of invasive species using ArcView GIS 3.3. This map was superimposed on GIS layers of major biomes in Africa based on WWF classification downloaded from the internet http://www.worldwildlife.org/science/data/item1874.html). These layers were used to identify biomes within which point locations fell. If a study did not provide coordinates, a search in Google Earth (downloaded from www.googleearth.com) was used to identify the study area coordinates as accurately as possible. The number of bird species negatively impacted per biome was then tallied and locations of the impacts mapped.

CHAPTER 3: RESULTS

Introduction

A total of 263 invasive species (excluding 35 invasive marine species) are currently listed in the Global Invasive Species Database as being invasive in Africa, (http://issg.org/database/).

Impacts of invasive plants on native birds

Negative impacts

At least 397 species of native birds have been negatively affected by invasive plants in Africa (Fig. 1, Table 2). However, this is an underestimate of the actual number of species affected because many studies did not list the species but grouped them under different categories. For example, Wonderfrash (2003) reported in general that gulls, herons, ducks and crakes are highly impacted by the Water Hyacinth (*Eichhornia crassipes*) in Ethiopia.

Habitat loss for breeding, foraging, roosting or cover accounted for the highest percentage (91%, n = 361) of native birds affected (Fig. 1). The negative effects of invasive plants mostly affected birds whose diets are dominated by invertebrates (Fig. 1).

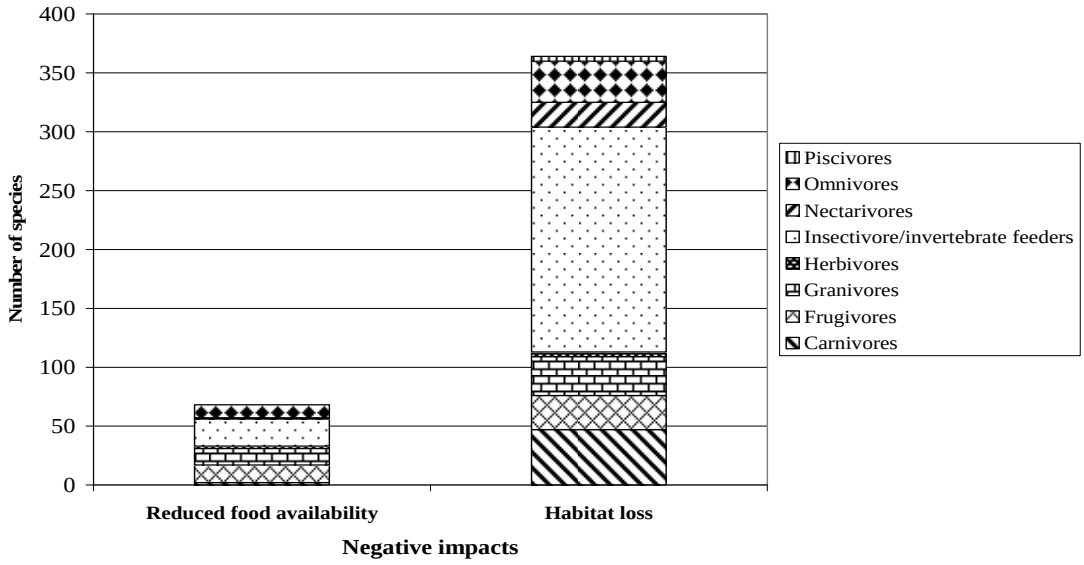

Figure 1. Total number of native bird species and feeding guilds negatively affected by invasive plants in Africa.

Positive impacts

At least 132 species of native African birds benefited from invasive plants (Table 2). Habitat suitability and food availability were the main contributors to these benefits (Fig. 2). An increase in the abundance or range expansion of at least 27 species of native birds was reported. Birds whose diets are dominated by invertebrates benefited most (Fig. 2).

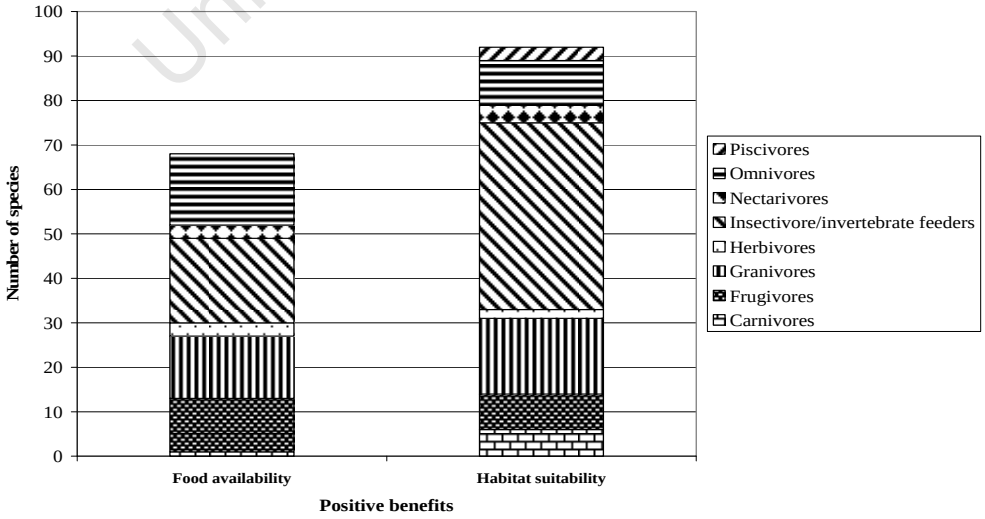

Figure 2. Total number of native bird species and feeding guilds benefiting from invasive plants in Africa.

Impacts of invasive invertebrates on native birds

Negative impacts

The effects of only a few invasive parasites, pathogens and diseases on native birds have been documented in Africa. Invasive pathogens that affect native birds in Africa include West Nile Virus, Avian Cholera, and Pittasine Beak and Feather Disease (PBFD).

At least 29 species of native birds have been negatively affected by invasive invertebrates in mainland Africa (Table 2). Of these, infection by pathogens affected the greatest number of species (n = 28, 97% -, Fig. 3). Only one case of predation by Red Ants (*Techmomyrmex albipes*) was reported. The feeding guild most negatively impacted was frugivores, followed by granivores (Fig. 3).

Positive impacts

At least two species of native birds are documented as having benefited from invasive invertebrates in Africa (Table 2). These include the African Black Oystercatcher (*Haematopus moquini*), which has benefited from invasion of an invasive mollusk that has improved the oystercatcher's food supply (Hockey & Schurink 1992; Coleman & Hockey 2008; Hockey 2009b). Another species that has benefited is the European Honey-Buzzard (*Pternis apivorus*) which is thought to have responded positively to the spread of the invasive Yellow Jacket Wasp (*Vespula germanica*) in the Western Cape, South Africa (Pepler & Martin 2002; Hockey et al. 2005).

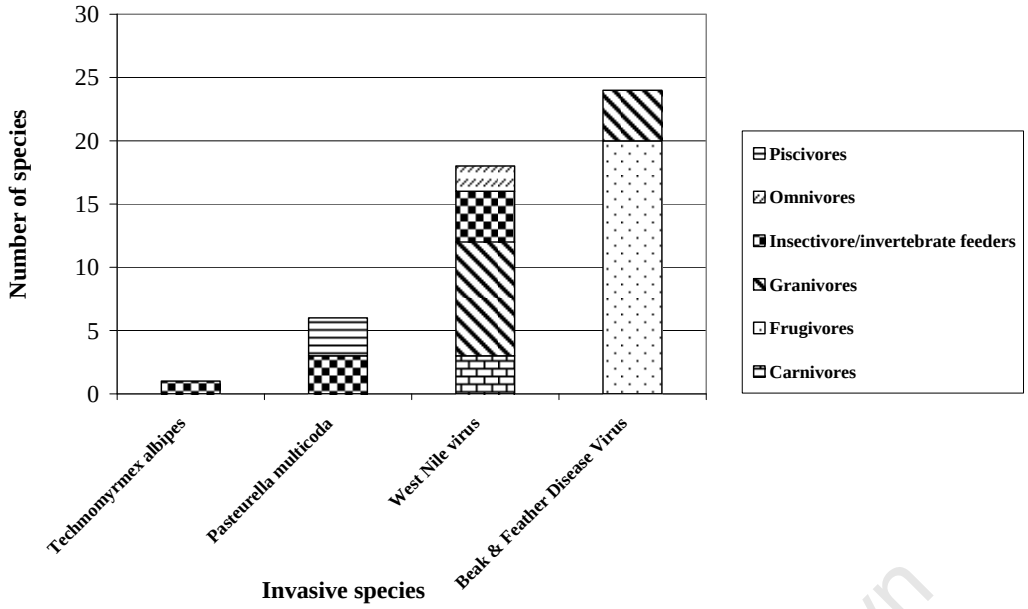

Figure 3. Total number of native bird species and feeding guilds negatively affected by invasive invertebrates and pathogens in Africa.

Impacts of invasive fish on native birds

Negative impacts

The most frequently reported responses of native birds as a result of invasive fish are diet shifts (Fig. 4). Other negative effects reported included habitat loss, population decrease, and competition for food. At least 14 species of native birds have been negatively impacted by invasive fish in Africa, most of which, unsurprisingly, are piscivores (Fig. 4, Table 2).

Figure 4. Total number of native bird species and feeding guilds negatively affected by invasive fish in Africa.

Positive impacts

The majority of the reported positive impacts of invasive fish on native birds were on increased food availability which resulted in population increase for some bird species. At least 13 species of native birds have benefited from invasive fish (Table 2), mostly as a result of increased food availability.

Impacts of invasive mammals on native bird species

Some of the invasive mammals that were reported to affect native birds in Africa include Domestic Cows (*Bos Taurus*), Domestic Sheep (*Ovis aries*), Domestic Goats (*Capra aegagrus hircus*), Domestic Dogs (*Canis lupis*), Domestic Pigs (*Sus scrofa*), House Mice (*Mus musculus*) and Brown Rats (*Rattus norvegicus*). No impacts from feral or Domestic Cats (*Felis catus*) were reported.

Negative impacts

Most of the reported negative impacts of invasive mammals on native birds in Africa involve domestic livestock which have caused overgrazing. Few studies reported the impact of invasive mammalian predators on native birds in mainland Africa. At least 154 African bird species have been negatively affected by invasive mammals (Table 2). The main negative impact on native birds was habitat loss (Fig. 5). The abundance of at least 120 species of native birds was reported to decrease in response to reduced food availability and unsuitable habitats caused by invasive mammals.

The guild most affected by alien mammals is that of species feeding on invertebrates (Fig. 5).

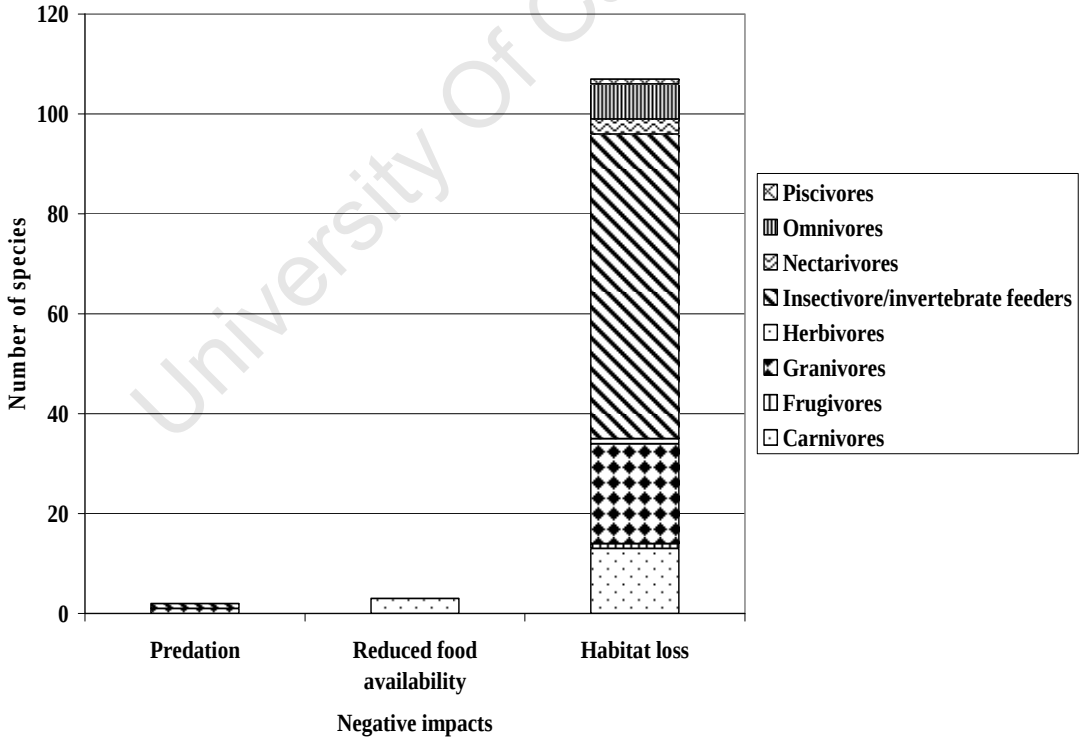

Figure 5. Total number of native bird species and feeding guilds negatively affected by invasive mammals in Africa.

Positive impacts

At least 57 species of native birds have benefited from the presence of alien mammals (Table 2). Habitat suitability for 15 species of native birds was reported. The abundance of at least 42 species of native birds was reported to increase in response to suitable conditions in the grazed areas.

Impacts of invasive birds on native bird species

In Africa, there are 13 invasive bird species listed in the Global Invasive Species Database. These include Common Myna, Mallard (*Anas platyrhynchos*), Greylag Goose (*Anser anser*), Canada Goose (*Branta Canadensis*), Cattle Egret (*Bubulcus ibis*), Feral Pigeon (*Columba livia*), House Crow, Monk Parakeet (*Myiopsitta monachus*), Ruddy Duck, House Sparrow (*Passer domesticu*), Red-whiskered Bulbul (*Pycnonotus jocosus*), Eurasian Collared Dove (*Streptopelia decaocto*) and Common Starling. However, this list is not exhaustive. For example, Rose-ringed Parakeet (*Psittacula krameri*) is also considered to be invasive in parts of Africa, including South Africa (Dean 2000) but is not included in the database.

Negative impacts

A number of negative effects of invasive birds on native birds in mainland Africa were reported. These include interspecific aggression, competition for resources, predation and hybridization.

A minimum of 74 species of native birds have been negatively affected by invasive birds (Table 2). Competition for resources accounted for the highest impact

followed by aggression and displacement (Fig. 6). House Crows impacted the highest number of native birds (n = 51) followed by Common Myna (n=7 - Table 1).

Positive impacts

No native bird species have been documented as benefitting from invasive birds (Table 2).

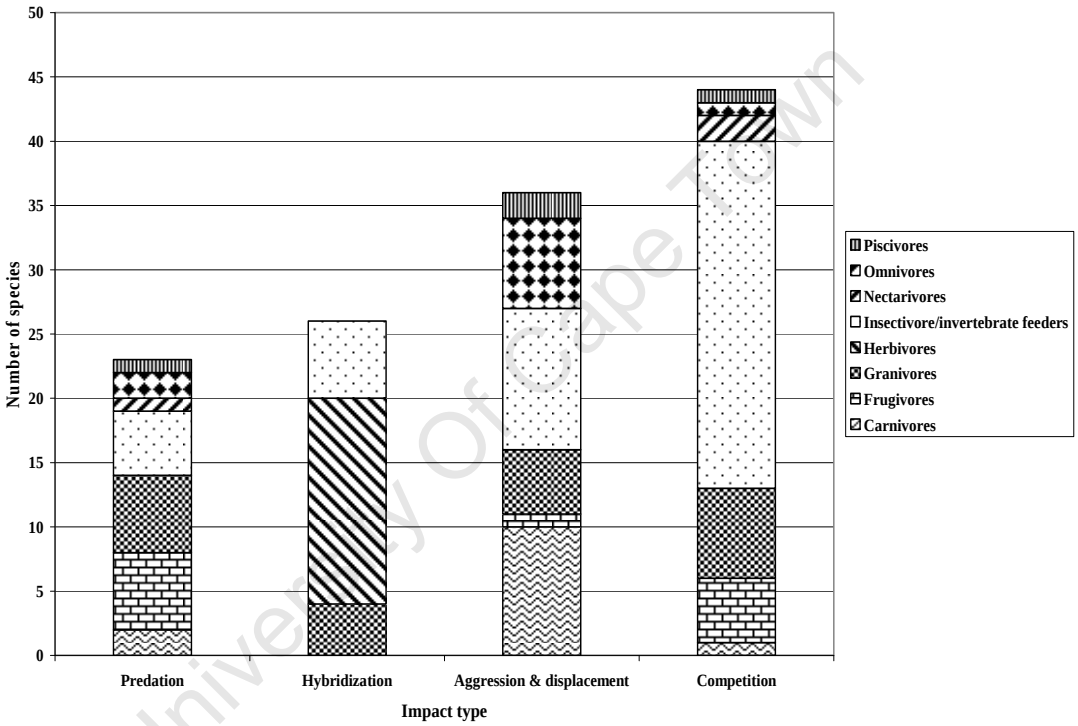

Figure 6. Total number of native bird species and feeding guilds negatively affected by invasive birds in Africa.

Table 1. Total number of native bird species affected by invasive birds.

Invasive bird	No. of bird species affected	% of total species affected
Corvus splendens	51	69.5
Acridotheres tristis	7	9.5
Sturnus vulgaris	6	8
Passer domesticus	6*	5
Anas platyrhynchos	3	4
Oxyura jamaicensis	2	3
Columba livia	1	1
Total	**74**	**100**

* includes two species which are also impacted by *Corvus splendens* and *Acridotheres tristis*.

Combined impacts from all invasive groups

Negative impacts

When invasive species from all the five taxa were combined, they negatively impacted on a total of 572 species of native birds (Appendix 1, Table 2). Invasive plants contributed most to the negative effects on native birds in Africa (Fig. 7). The most negatively impacted feeding guild was the insectivore/invertebrate feeders (Fig. 7, 8). This guild comprised 84% (n=483) of all native species of birds reported to be negatively impacted by invasive species from the five taxa.

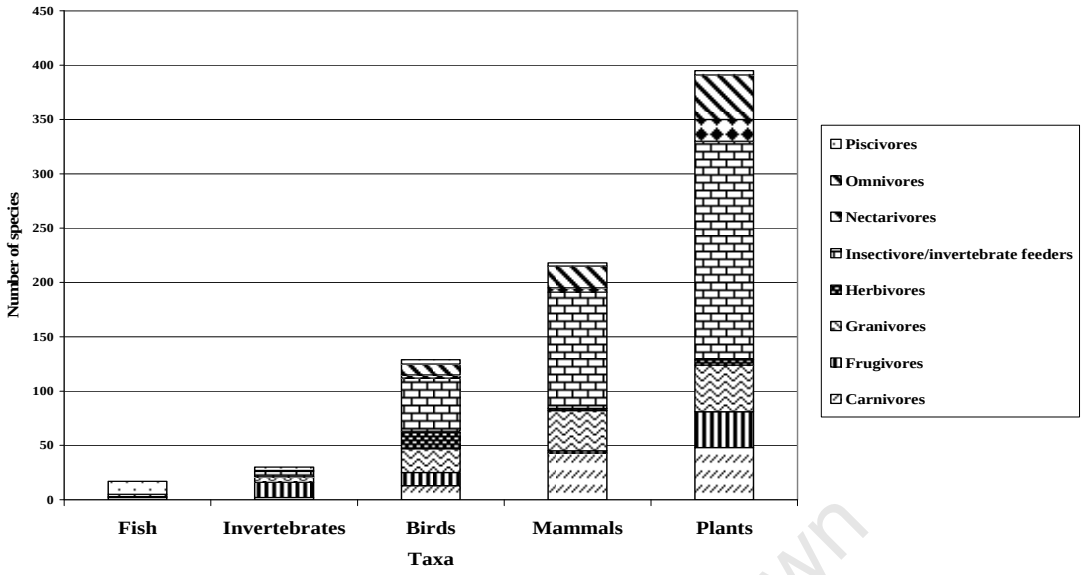

Figure 7. Total number of native bird species negatively impacted by invasive species in Africa.

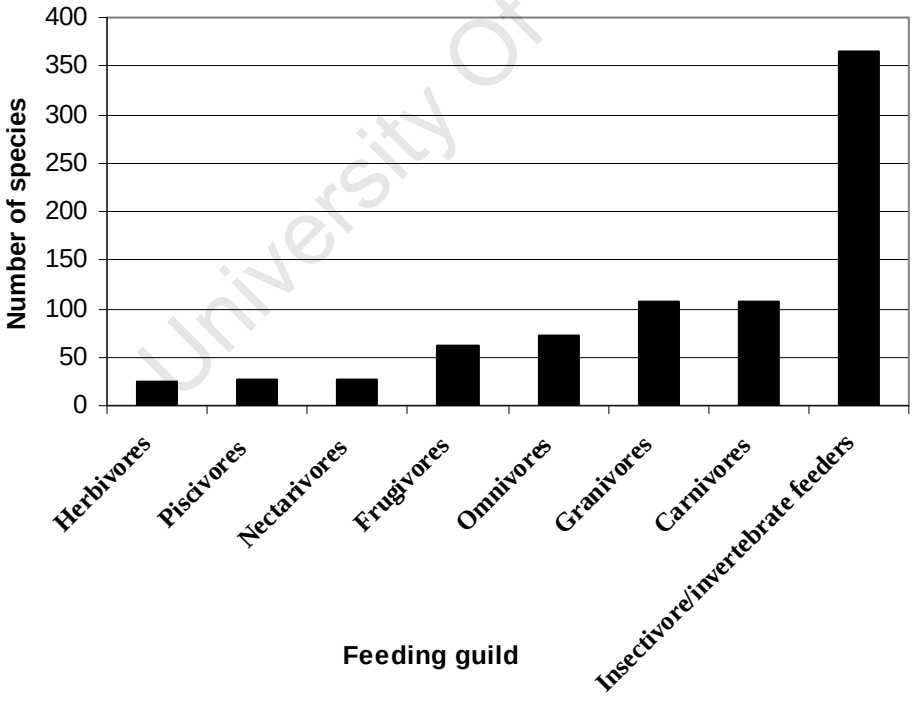

Figure 8. Total number of native bird species per feeding guild negatively impacted by invasive species in Africa.

Positive impacts

A total of 191 species of native birds benefited from invasive species in the five taxa that were reviewed (Appendix 2, Table 2). As with those guilds most impacted negatively, most of the species that benefited from invasions were insect/invertebrate feeders (Fig. 9 & 10).

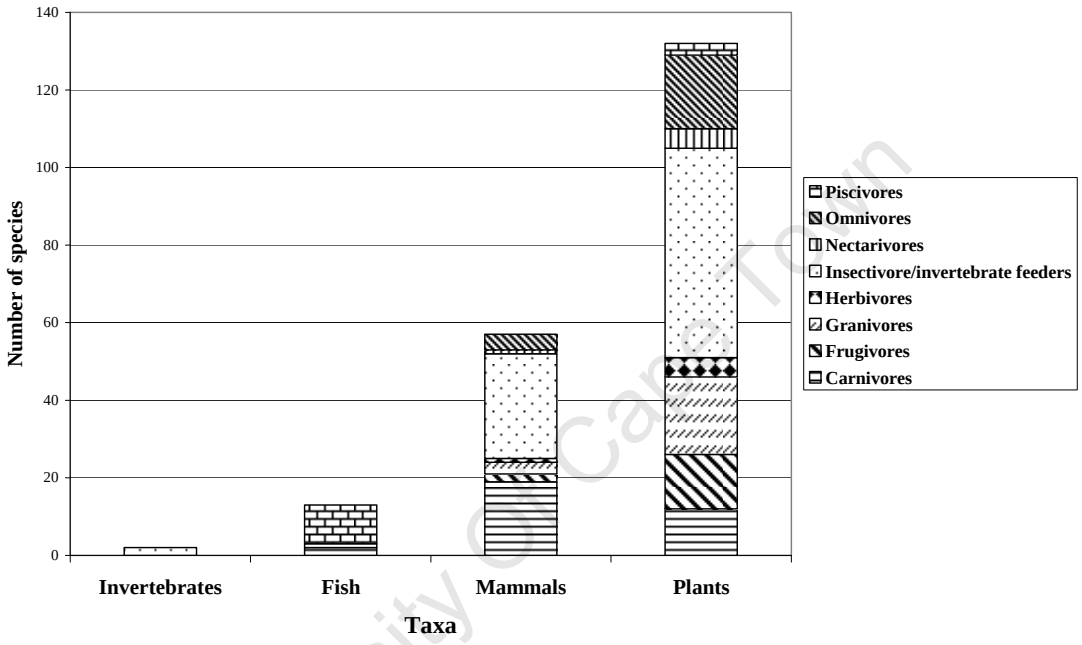

Figure 9. Total number of native bird species benefiting from invasive species.

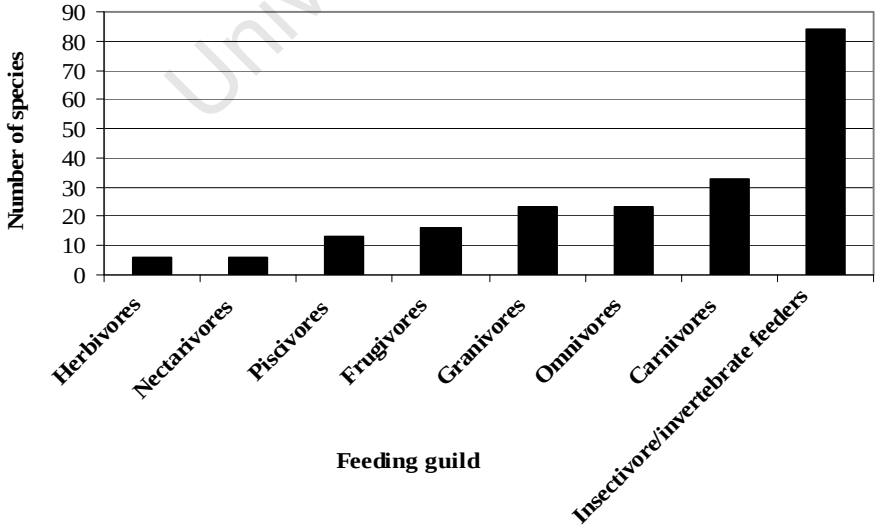

Figure 10. Total number of native bird species per feeding guild benefiting from invasive species in Africa.

Table 2. Total number of native bird species affected by invasive species.

Taxa	No. of bird species negatively affected	No. of bird species benefiting
Plants	397	132
Invertebrates	29	2
Fish	14	13
Mammals	154	57
Birds	74	0
Total number of species	**572***	**191***

* These figures are not a summation of the columns because several birds were affected by invasive species from more than one taxa.

Extent of invasions across biomes

The most negatively impacted biomes were montane grasslands and shrublands (Fig. 11, Table 3).

Table 3: Total number of native bird species negatively affected by invasive species by biome.

Biome	Number of bird species affected
Flooded grasslands and savannas	25
Lakes	31
Tropical & subtropical moist broadleaf forests	57
Mangrove (subtropical & tropical, salt water inundated)	64
Mediterranean forests, woodlands, & scrub forests	132
Deserts & xeric shrublands	171
Tropical & subtropical grasslands, savannas, & shrublands	213
Montane grasslands & shrublands	361

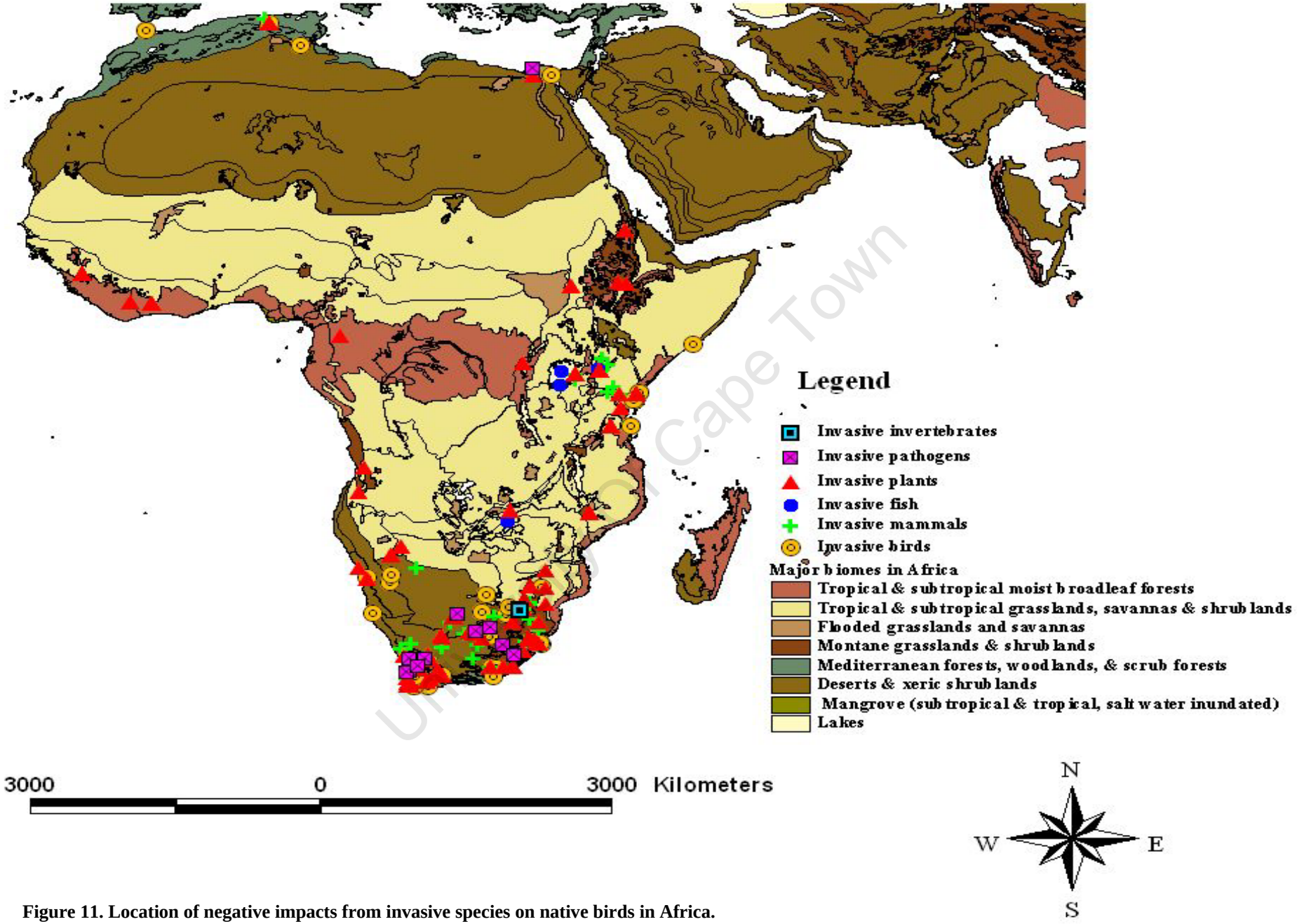

Figure 11. Location of negative impacts from invasive species on native birds in Africa.

CHAPTER 4: DISCUSSION

Biological invasions are significant contributors to biodiversity loss (Vitousek et al. 1997). Although biological invasions are often associated with negative impacts, it is also important to appreciate that in some instances they have positive consequences for native biodiversity.

In Africa, as in other parts of the world, the magnitude and consequences of invasive species on native species varies geographically. Birds are one of the relatively well-studied taxa and sensitive to changes caused by biological invaders (Hockey 2003). A high number of native African birds (572 species) have been negatively affected by biological invaders. This represents *ca* 29% of all the bird species in Africa (including its satellite islands). This finding is consistent with the report by BirdLife International (2008) that invasive species affect large number of native birds, including threatened ones.

Contribution of invasive species to impacts on native birds by taxa

There are differences in the extent of impacts of invasive species from different taxa on native birds in Africa. These differences in taxonomic contribution underscore some important underlying patterns of invasions.

Impacts from invasive plants

Relative to other taxa, invasive plants were responsible for the majority of both negative and positive effects on native birds, although the former outnumber the latter by some 33% (Table 2). Amongst the negative impacts on native birds caused by invasive plants, habitat loss (when native plants are replaced by aliens) and the

consequent reductions in native bird diversity dominated. This finding is consistent with studies elsewhere that have highlighted the significance of habitat loss from biological invasions in reducing native avian biodiversity (e.g. Vitousek et al. 1997; Crooks 2002; Levin et al. 2003; BirdLife International 2008). For example, in this study, decreases in avian species richness and density were reported in most of the studies of invasive plants, especially those that form dense monotypic stands resulting in structural homogenization of the habitat.

There are many invasive plants in Africa, but their presence and impacts are not randomly distributed. For example, at least 200 plant species are invaders in Africa north of the Sahara (Floc'h et al. 1990) whereas South Africa alone has *ca* 180 invasive plants (Richardson & van Wilgen 2004). Some of these invasive plants are reported to transform ecosystems either by consuming, adding or redistributing resources (Richardson et al. 2000a; Yelenik et al. 2004). The net effects of these transformations include alteration of biogeochemical and hydrological cycles, and trophic and physical changes in the environment (Vitousek 1990; Yelenik et al. 2004). One example is the nitrogen-fixing *Acacia saligna* which facilitates growth of the weedy grass *Ehrharta calycina* in the fynbos biome of South Africa (Yelenik et al. 2004).

Invasive plants may also cause habitat loss through replacement of many native plants. For example, the main invasive plants in Southern Africa – *Acacia* spp., *Hakea* spp., and *Pinus* spp. are estimated to threaten over 50% of native plants (Macdonald et al. 1989). All these transformations affect native birds, especially through habitat loss. For example, many studies in South Africa have documented the impacts of several invasive plants on native birds (e.g. Winterbottom 1970;

Breytenbach 1986; Knight 1986; Fraser 1990a; Macdonald 1991; Dures 2009). Reported effects include reduced density and species richness, loss of breeding habitat and altered diet.

In aquatic ecosystems, the Water Hyacinth (*Eichhornia crassipes*) from South America has invaded rivers and lakes in 23 African countries (GISP 2007). Despite this widespread distribution, its impact on native birds is poorly understood, but a few studies do highlight the dire consequences of the invasion. For example, Wonderfrash (2003) reported that Water Hyacinth threatens at least 204 wetland-dependent species in Ethiopia, including the *Endangered* Wattled Crane (*Bugeranus carunculatus*). The Akaki Wetland near Addis Ababa is no longer used by waders due to total invasion by the plant (Wonderfrash 2003).

Birds that are habitat specialist may be particularly vulnerable to plant invasions. In some areas, grassland specialists have lost their habitat from plant invasions. For example, grassland specialists are absent from Bramble (*Rubus cuneifolius*) invaded areas in the mist-belt grasslands of KwaZulu-Natal, South Africa (Lipsey & Hockey in press).

Comparatively few studies have investigated the impacts of invasive plants on native birds in African countries other than southern Africa. In the Lamto Reserve forest, Côte d'Ivoire, several raptors have been affected by the invasive plant, (*Chromolaena odorata*) (Thiollay 2000), which has changed the physical structure of the forest. This change benefited some resident and migratory raptor species while others lost their habitat. Although alien invasives are not the only threat to raptor population in the area, the decrease of the African Cuckoo Hawk (*Aviceda*

cuculoides), for example, was largely attributed to invasion by *Chromolaena* (Thiollay 2000).

Some plantation trees in Africa are invasive and have benefited native birds, while other species have been negatively impacted. For example, *Acacia*, *Eucalyptus* and *Pinus* spp. were extensively planted in South Africa's afforestation programme but have become invasive (Richarson et al. 1994; Le Maitre et al. 2002). A number of studies have documented loss of roosting, breeding or foraging sites for many native birds in such plantations (e.g. Allan & Tarboton 1985; Armstrong & Hensbergen 1994; Allan et al. 1997; Wethered 2001).

For example, in a study in KwaZulu-Natal, Wethered (2001) showed that there are species-specific responses of native birds to the invasive *Pinus patula* and *Acacia mearnsii.* Findings from the study showed that the resultant fragmentation of natural forests by commercial plantations predisposed larger, naturally low abundant and insectivorous species of native birds to local exctinction. On Mount Mulanje, Malawi, the only endemic bird in the country - Yellow-throated Apalis (*Apalis flavigularis*) is threatened by the invasive *Pinus patula* (Mzumara 2009). The invasive plantation trees may also reduce the diversity and abundance of invertebrates, which in turn may affect native birds. For example, in South Africa, Samways et al. (1996) reported that *Acacia longifolia*, *A. mearnsii* and *Pinus patula* (all invasive) plantations supported impoverished invertebrate communities.

The presence of some of the invasive plantation trees has, however, benefited some native birds by providing nesting sites. One example is availability of suitable nest sites provided by the invasive *Pinus patula, Populus* sp., *Acacia mearnsii,* and *A.*

saligna to raptors in many parts of South Africa (Allan & Tarboton 1985; Malan & Robinson 2001).

Invasive grasses can have negative ecological impacts on native birds. Despite the importance of invasive grasses as contributors of biodiversity loss, very little is known about their ecological impacts in South Africa (Milton 2004) and, by extension, the rest of Africa. Studies addressing the impact of invasive grasses on native birds were noticeably lacking.

Based on this study, habitat suitability and food availability contributed most to the benefits derived by native birds from invasive plants (Fig. 2, Table 2). Many studies report native birds feeding on and dispersing a wide variety of invasive plants in Africa. For example, Glyphis et al. (1981) reported several native bird species feeding on invasive food plants including *Lantana camara*, *Melia azedarach*, *Ziziphus mucronata* and *Acacia cyclops* in the Cape Peninsula, South Africa. The study also reported increased germination of seeds eaten by the birds, thus facilitating their spread.

Apart from the increased food availability provided by invasive food plants, native birds may be attracted to them because of changed fruit displays and predictable production (Knight 1986; Gosper et al. 2005; Milton et al. 2007). For example, *Acacia cyclops* has large and conspicuous fruit displays and more predictable fruit production than native plants and hence attracts many frugivores (Knight 1986). This may lead to an increase in the abundance of those native birds (e.g. Fraser 1990a). However, whilst there may be some benefits to native birds, their feeding actions can lead to further spread of the invasive plants and this may alter native plant-native bird mutualisms (Traveset & Richardson 2006).

Mutualistic bird-plant associations develop over evolutionary timescales (Traveset & Richardson 2006). These associations may, among others, include pollination or seed dispersal (Richardson et al. 2000b; Traveset & Richardson 2006). It has been suggested that specialized bird-plant associations may be disrupted by invasive species (Siegfried 1973; Traveset & Richardson 2006). This is especially true when invasive plants displace native plants thus disrupting the association between the native birds and indigenous plants.

Even though native birds can benefit from alien invasive plants as food sources and facilitate their spread (Richardson et al. 2000b), it nevertheless constitutes disruption of their normal diet (Oatley 1984; Fraser 1990b; Knight & Macdonald 1991). The birds may therefore be forced to feed almost exclusively on the food resource provided by the invasive plant for lack of alternative food source (Oatley 1984). There are some examples of studies in Africa that report this effect.

For example, Knight & Macdonald (1991) reported Southern Black Korhaans (*Eupodotis afra*) feeding mainly on invasive *Acacia cyclops* in South Africa. Barn Swallows (*Hirundo rustica*) also ate and dispersed substantial amounts of *Acacia cyclops* seeds in the Western Cape, South Africa (Underhill & Hofmeyr 2007). The study reported that *ca* two million seeds were eaten by 3000 Barn Swallows within five months. Swallows are normally insectivorous and therefore this represents a change in diet. Redwinged Starlings (*Onychognathus morio*) also feed on *Acacia cyclops* seeds in South Africa (Fraser 1990b). In Namibia, the Double-banded Sandgrouse (*Pterocles bicincutus*), Cape Turtle Dove (*Streptopelia capicola*), and Laughing Dove (*S. senegalensis*), among other species, were reported to feed on over

1000 seeds of the invasive *Datura innoxia* (Brown et al. 1985; Jones & Jankowitz 1985).

Exclusive use of invasive plants favouring native birds has been reported in some studies. For example, *Lantana camara* provides suitable habitat for the *Threatened* Hinde's Babbler (*Turdoides hindei*) in some parts of Kenya and the species occurs exclusively in the invaded habitats (Njoroge & Bennun 2000). Other studies report that native birds may prefer invasive food plants over indigenous ones. For example, in the South-western Cape, South Africa, Red-winged Starlings preferred feeding on *Acacia cyclops* fruits over indigenous ones (Knight 1986) .

In some instances, the presence of alien plants has been shown to result in population increase and range expansion of native birds (e.g. Macdonald 1986, 1990; Hockey et al. 1989; Hockey 2003; Okes et al. 2008; Hockey & Midgley 2009). For example, Hockey et al. (1989) reported that 37 species of birds in the South-western Cape, South Africa, had expanded their range and attributed this to alien vegetation. Of the 132 species that appear to have benefited from invasive plants across Africa, only 27 species were identified as increasing in abundance and or extending their ranges as a result.

One of the species which has greatly benefited from invasive plantation trees in South Africa is the Black Sparrowhawk (*Accipiter melanoleucus*); its range has expanded and population increased (Allan & Tarboton 1985; Curtis et al. 2007). Another example of a bird whose range expanded due to an invasive plant is the Southern Masked-Weaver (*Ploceus velatus*). Macdonald (1986) attributed range expansion of this native bird in the Karoo biome, South Africa to the invasion by mesquites *Prosopsis* spp. In contrast, habitat loss as a result of invasive and non-

invasive alien vegetation on native birds was linked directly to range or population decrease of 56% of bird species whose ranges had contracted in the South-western Cape, South Africa (Hockey et al. 1989).

Impacts from invasive invertebrates

The impacts of invasive invertebrates on native birds in Africa are not well documented. For example, quantitative studies of depredation of bird nests by invasive Argentine and Red-imported Fire Ants were generally lacking, despite the fact that such depredation is known to occur (e.g. Earlé 1985; Allen et al. 2004; Suarez et al. 2005). Some invasive ants impact on birds by displacing native arthropods (e.g. Matilya 2003; Lach 2007, 2008; Raharinjanahary 2007) and preying on nest contents (e.g. Earlé 1985; Suarez et al. 2005). Displacement of native arthropods may change the trophic dynamics of an area, including food availability for birds, while nest predation directly impacts on reproductive success (Suarez et al. 2005). Suarez et al. (2005) provided experimental evidence that the invasive Argentine Ants (*Linepithema humile*) depredate bird nests and can have a particular impact on ground-nesting species. The study also reported widespread avian nest mortality in USA caused by Argentine Ants and Red-imported Fire Ants. One study reported nest predation of South African Cliff-Swallows (*Hirundo spilodera*) by invasive Red Ants (*Techmomyrmex albipes*) in the Free State, South Africa (Earlé 1985).

Invasive invertebrates can also directly or indirectly affect bird-plant relationships through facilitation or disruption of the system (e.g. Traveset & Richardson 2006). Many studies in Africa report displacement of arthropods by invasive ants (e.g. see Bond & Slingsby 1984; Matilya 2003; Lach 2007, 2008;

Raharinjanahary 2007) and these have possible negative consequences for native birds. For example, failure of seed recruitment of native plants in the Cape fynbos, South Africa, due to depredation of seeds by Argentine Ants, may have direct and negative effects on granivorous birds (Holway et al. 2002). More serious consequences may be expected if the displacement causes extinctions of some species through cascading effects. For example, Bond and Slingsby (1984) proposed a possible collapse of native ant-protea mutualisms and subsequent extinction of endemic Proteaceae in the fynbos due to displacement of native ants by Argentine Ants. This in turn could affect birds like the Protea Seedeater as a result of food-web disruption.

In South Africa, some studies suggested that the Argentine Ants may have negative effects on bird pollinators through displacement of floral arthropods in the Cape Floristic Region (Lach 2008) while Buys (1987) reported that the same ants collected substantial amount of nectar from the flowering plants in the area, possibly reducing nectar availability for birds. Another study at Lopé National Park in Gabon reported displacement of native ants by the invasive Little Fire Ant (*Wasmannia auropunctata*) (Walker 2006) and this may have potential negative effects on native birds.

There is a scarcity of data on the impacts of invasive pathogens and diseases, although a few studies have shown that invasive pathogens can have substantial negative impacts on native birds in Africa (e.g. Williams & Ward 2002; Kondiah 2004). Invasive parasites, pathogens and diseases can affect native birds and may be spread by invasive species from other taxa. For example, House Sparrows (*Passer*

domesticus) have been implicated in the spread of ectoparasites across continents (Brown & Wilson 1975).

There are several invasive pathogens and diseases that have affected native birds globally. For example, Avian Cholera (*Pasteurella multocida*) is thought to be native to the Bengal and Ganges River Delta in India (Hays 2005). The first pandemic of the disease was recorded between 1817 and 1824 when it spread to other countries, reaching eastern Africa in the early 1820s. Hays (2005) reported that the spread was facilitated by military and colonization activities and improved means of travel. Outbreaks of the disease have been reported worldwide and affect over 100 different bird species, particularly waterfowl in North America (Botzler 1991).

Avian Cholera outbreaks on islands can be particularly harmful to small populations of native birds because they can result in local extinction. For example, there is a high possibility that the critically *Endangered* Amsterdam Albatross (*Diomedea amsterdamensis*) will go extinct as a result of the introduction of Avian Cholera to Amsterdam Island (Weimerskirch 2003). The disease was probably unintentionally introduced by researchers and tourists visiting the island (Gardner et al. 1997). In South Africa in 1991, Avian Cholera caused mass mortality of thousands of *Near-threatened* Cape Cormorants (*Phalacrocorax capensis*) at eight islands (Crawford et al. 1992). Another outbreak in South Africa in 2002 killed *ca* 14,000 Cape Cormorants on Dyer and Bird Islands (Williams & Ward 2002). In the same year, an additional 10,000 birds, including Cape Cormorants, died on the Atlantic coast of South Africa's Western Cape Province from the disease (Williams & Ward 2002).

Studies have documented the negative effects of viruses on native birds. For example, the Psittacine Beak and Feather Disease Virus usually affects parrots and has been documented in more than 40 different parrot species worldwide (Kondiah 2004). The virus is highly infectious and often fatal. It is thought to have originated from Australia but is currently global in distribution (Blackburn et al. 2009). In southern Africa, infection from the virus threatens the *Endangered* Cape Parrot (*Poicephalus robustus*) and the *Vulnerable* Black-cheeked Lovebird (*Agapornis nigrigenis)* (Heath et al. 2004; Kondiah 2004).

Another invasive virus that has affected native birds in Africa is the West Nile Virus. The virus was first reported in Uganda in 1937 and has spread to other parts of Africa, the Middle East and southern Europe (van der Meulen et al. 2005). Increasingly frequent outbreaks of the virus have been recorded in Algeria, Tunisia and Morocco since the 1990s (Matthews & Brandt 2004). About 150 bird species worldwide have been recorded as carrying the West Nile Virus (van der Meulen et al. 2005). Most of the infected birds are passerines and the disease is reported to cause heavy mortality in some outbreaks (Work et al. 1955; Komar et al. 2003). For example, thousands of wild and domestic birds died in New York City in 1999 from West Nile Virus infection (Komar et al. 2003). In South Africa, McIntoch (1976) reported very high infections of the virus in different species of birds. These infections were reported to be prevalent at Upington, Northern Cape in 1974 and affected at least seven native birds as well as the invasive House Sparrow. In particular, the study singled out House Sparrows, Southern Masked Weavers (*Ploceus velatus*) and Southern Red Bishops (*Euplectes orix*) which had weak antibody responses, even though there was no evidence of the infections causing mortality.

Few studies in Africa have investigated benefits that native birds derive from invasive invertebrates. However, the example of the African Black Oystercatcher benefiting from the invasive Mediterranean mussel in South Africa (Hockey & Schurink 1992; Coleman & Hockey 2008; Hockey 2009b) shows that there can be significant benefits. In this particular instance, the benefit was derived from an increased biomass of food on the shore, leading to an increase in average breeding success and a decrease in average territory size. The European Honey-Buzzard has also benefited from the invasive Yellow Jacket Wasp in the Western Cape, South Africa (Pepler & Martin 2002; Hockey et al. 2005). Honey-Buzzards usually inhabits wooded areas in sub-Saharan Africa and may be benefiting from the presence of pine plantations in the Western Cape where the invasive social wasps have recently invaded (Hockey et al. 2005).

Impacts from invasive fish

There are many invasive fish species that have been introduced in African waters for various purposes. These include improvement of fisheries for food production, sport fishing, control of mosquitoes, or as ornamentals. Most of the introduced fish have become invasive (e.g. Bruton 1986; Bruton & van As 1986; Kudhongania & Chitamwebwa 1995; Marshall 1995; Pitcher et al. 1995) and pose a potential threat to native fish and birds. In this study, very few invasive fish species were found to have either negative or positive impacts on native birds (Fig. 4, Table 2).

An example of the negative impacts is the introduction of the Common Carp (*Cyprinus carpio*) which is established in 15 African countries (Jenness et al. 2007). The Common Carp is reported to cause wetland degradation in Africa thus affecting waterbirds such as the White-headed Duck (*Oxyura leucocephala*) (CMS Technical

Series 2006). In southern Africa, there are at least 64 invasive fish species (Bruton 1986), of which Common Carp is the most widespread in the region's drainage basins (Bruton & van As 1986). These invasive fish are reported to have negative ecological effects on other native fish (Bruton & van As 1986).

Population decreases of some native birds as a result of fish invasions have also been reported. For example, introduction of the invasive Red Swamp Crayfish (*Procambarus clarkia*) into Lake Naivasha, Kenya was implicated in the decline of Red-knobbed Coots (*Fulica cristata*) (Harper et al. 2002). The crayfish was reported to eat and deplete aquatic macrophtytes and consequently reduce food availability for coots.

Few studies have reported positive impacts of invasive fish on native birds. At Lake Kariba in Zambia and Zimbabwe, the introduced Lake Tanganyika clupeid (*Limnothrissa miodon*) makes up the bulk of fish biomass in the Lake (Marshall 1995). Marshall (1995) suggested that the White-winged Tern (*Chlidonias leucopterus*) has benefited by feeding on *L. miodon.* Though they do not feed on live *L. miodon*, the Grey-headed Gull (*Larus cirrocephalus*) also benefited by scavenging fish from racks on which *L. miodon* and other fish are sun-dried (Marshall 1995). Another example is the introduction of barbs (*Barbus* sp.) and Brown Trout (*Salmo trutta*) in KwaZulu-Natal, South Africa, which benefited the African Darter (*Anhinga rufa*) and resulted in a local range expansion (Ryan 2005).

Overall, however, there is little evidence that invasive fish are having widespread impacts on native birds, despite the fact that invasive and non-invasive alien fish are having major negative impacts on native fish in Africa's lakes and rivers (Goudswaard & Wanink 1993; Kudhongania & Chitamwebwa 1995; Marshall 1995;

Pitcher et al. 1995; Goudswaard et al. 2008). It is therefore reasonable to predict cascading effects across trophic levels with resultant effects on native birds, especially piscivores, in these same ecosystems.

Impacts from invasive mammals

Introduced mammals can have serious ecological consequences for biodiversity (Spear & Chown 2009). Invasive mammals were the second most significant contributor to effects of invasive aliens on native birds in Africa (Fig. 7, Table 2). In mainland Africa, the major negative impact of invasive mammals is overgrazing (e.g. Walker et al. 1981), which can result in reproductive failure and range contractions (e.g. Muchai 2002). This contrasts markedly with the effects of alien mammals on Africa's satellite islands, where their main impact is predatory (e.g. Hockey 2009a). It is generally appreciated that overgrazing and trampling changes the vegetation structure, primarily through the removal of the understorey plants (Muchai 2002) although it can also lead to bush encroachment (e.g. van Vegten 1984; Skarpe 1991; Wiegand et al. 2006).

There may also be changes in the composition and density of plant species, especially those that are grazed or browsed. All these vegetation changes may affect avian fauna in grazing areas. For example, major changes in bird populations in southern Africa have resulted from overgrazing (Macdonald 1992). In the Northern Cape, Free State and former Transvaal, livestock degradation of vleis and marshes was implicated in the decline of the Wattled Cranes (*Bugeranus carunculatus*) (Macdonald 1992). Overgrazing or excessive pasturage by cattle, goats and sheep also threatens some native birds in west African forests (Collar & Stuart 1985). Forests in Africa cover *ca* 22% of its surface area and provide grazing areas for livestock

(UNEP 2009). Due to human population increase and consequent land shortages, people are forced to look for alternative grazing areas, including forests (e.g. Allaway & Cox 1989; Darkoh & Rwomire 2003). Livestock grazing may therefore compete with other forms of land use, the resultant effect being overgrazing in some forests (Allaway & Cox 1989).

Overstocking can also impact ground-nesting birds whose eggs are at risk from trampling. One of the consequences is reproductive failure leading to population declines. For example, a study by Muchai (2002) reported poorer nesting success, lower abundance, decreased species richness and changes in the distribution of most native birds as a result of heavy grazing in Wakkerstroom district, South Africa. The study suggested that overgrazing increased the risk of nest predation due to reduced vegetation cover. In the Aberdare Mountains and the Mau-Narok/Molo regions of Kenya, the nests of the Aberdare Cisticola (*Cisticola aberdare*) are also vulnerable to damage by livestock (BirdLife International 2009b). North of the Sahara, the range of the threatened (and recently discovered) Algerian Nuthatch (*Sitta ledanti*) is mostly restricted to Mount Babor in Algeria. It is currently threatened by overgrazing from livestock, including pigs (Collar & Stuart 1985). In winter, the birds feed mainly on the nuts and seeds of four tree species: overgrazing is threatening the regeneration of these tree species (BirdLife International 2009c).

In addition to the biological effects of overgrazing, physical disturbance by livestock further contributes to the large number of bird species negatively affected. Consequently, some native birds avoid overgrazed areas. For example, in South Africa, Jansen et al. (1999) reported several grassland birds being absent from heavily grazed areas. Another example is a total absence of Layard's Titbabbler (*Parisoma*

layardi) and Cape Long-billed lark (*Mirafra curvirostris*) in overgrazed areas at Paulshoek, South Africa (Joubert 1998). In Uganda's pastoral areas, the total number of grassland species of birds is slightly lower in grazed than ungrazed areas (Asasira & Pomeroy 2008). The mechanism underlying these negative effects on birds in heavily grazed areas is thought to be reduced food availability and elevated nest predation rates (Muchai 2002).

Invasive mammals may also compete with native birds for food and facilitate the spread of invasive plants. For example, competition for food with Domestic Pigs has been implicated in regional extinction of the Egyptian Vulture (*Neophron percnopterus*) in South Africa (Anderson 2000b). Spear and Chown (2009) reported that the impacts of Feral Pigs on bird declines and even extinctions (on islands) globally are substantial. On the other hand, the Grey Squirrel (*Sciurus carolinensis*) disperses the seeds of the English oak (*Quercus robur*) (Knight 1988) and *Pinus pinea* in the Western Cape, South Africa (Richardson et al. 1990). This has the potential effect of spreading and maintaining the alien plants by squirrels and although not documented, it has implications for food availability to granivorous birds.

Predation of native birds by invasive mammals on the African mainland is not widely reported, but may have significant impacts. For example, studies have documented the negative impacts of feral cats (*Felis catus*) on native birds (e.g. Blackburn et al. 2004) but this is not documented in Africa. Based on the negative impacts of feral cats in other regions, and especially on islands, their impacts on Africa's biodiversity are likely to be significant. In Namibia, the Brown rat (*Rattus rattus*) and Nowregian Rats (*R. norvegicus*) are potential threats to ground-nesting birds at Sandwich Harbour and Lüderitz, respectively (Griffin & Panagis 1985). It is

reasonable to expect that the Feral and Domestic Cats, Brown Rats, Norwegian Rats and House Mice may all be having substantial predatory impacts on native birds in Africa but these effects are largely undocumented.

Impacts from invasive birds

Invasive birds like the House Crow, Common Myna and Common Starling are the subject of many studies due to their widespread invasion and impacts on native birds in many parts of the world (Feare & Mungroo 1990; Ryall 1992; Lowe et al. 2000; Marzluff 2001; Nyári et al. 2006). Some of these invasive birds have multiple negative effects on native bird species. For example, of Africa's invasive alien birds, the House Crow impacts by far the greatest number of native bird species (Table 1). These effects include harassment, displacement and predation, which lead in some cases to population decreases and local extinctions, illustrating the multiplicity of impacts that a single invasive bird can have on species and communities of native birds.

Studies in Africa have documented harassment by House Crows and displacement of native birds at nesting sites that disrupted their breeding behaviour (e.g. Patten 1957; Masterson 1976; Earlé 1985; Brooke et al. 1986; Ryall & Reid 1987; Ryall 1992; Feare & Craig 1998). This has caused population reductions among native birds. For example in Mombasa, Kenya, House Crows harassed and displaced at least 22 native species leading to population decreases among most of them (Ryall 1992).

Invasive birds can become predators of native bird species. For example, eastern Africa has experienced local extinctions of sunbirds and weavers due to

predation and displacement by House Crows (Ryall 1992). In Bloemfontein, South Africa, entire colonies of the South African Cliff-Swallows deserted their nests due to harassment and depredation by House Sparrows (Earlé 1985).

Another well documented negative consequence of invasive birds is hybridization with native birds (e.g. Gray 1958; Johnsgard 1968; Johnsgard 1978; McCarthy 2006): this is especially prevalent among waterfowl (Johnsgard 1978). The negative consequence of hybridization is often considered to be genetic introgression (Simberloff 1996). Potential genetic extinction of native birds as a result of hybridization with invasive species has been reported in the literature (e.g. Rhymer & Simberloff 1996).

Mallards hybridize with at least 40 other waterfowl species (Johnsgard 1968), especially ducks of the genus *Anas* (Banks et al. 2008). Hybridization between mallards and South African ducks is considered to be a real threat to native waterbirds (Greig 1980; Banks et al. 2008). For example, Mallards are a threat to the Yellow-billed Duck (*A. undulata*) with which they hybridize in South Africa (McCathy 2006). Mallards are a further concern because they harass, displace and compete for food with native waterbirds (Banks et al. 2008).

Introgressive hybridisation between invasive Ruddy Ducks and native White-headed Ducks in several northern African countries has been identified as a critical issue (CMS Technical Series 2006). A possible future threat exists in eastern and southern Africa from hybridization between Ruddy Ducks and the indigenous Maccoa Duck (*O. maccoa*) (Owen et al. 2002). In sub-Saharan Africa, there is also widespread interbreeding between Feral Pigeons and Rock Pigeons (McCarthy 2006).

Based on this study, native birds have not benefited from invasive birds. However, such benefits could occasionally arise. For example, both the African Goshawks (*Accipiter tachiro*) and Black Sparrowhawks (*Accipiter melanoleucus*) have expanded their range into Cape Town, South Africa and may be preying on Feral Pigeons and Common Starlings (Hockey 2003). Thus native raptors would benefit from increased food availability from invasive birds.

Contribution of invasive species to impacts on avian functional groups

Native birds that feed on insects and other invertebrates are disproportionally affected (55%, both positively and negatively) by invasive species (Figs. 8 & 10). This response was observed across all invasive taxa except fish and invertebrates. This suggests that invasive species in Africa are causing widespread reductions in food availability for invertebrate-feeding birds. However, it is also likely that there may be more insectivorous species than other feeding guilds hence the high number of birds affected.

Compared to the invertebrate-feeding birds, there were few birds from other feeding guilds that were negatively affected (Fig. 8). However, even among these guilds, local effects can be severe. For example, in the fynbos biome, South Africa, there was complete loss of nectarivores and frugivores in *Hakea sericia*-invaded areas (Breytenbach 1986). This included the locally endemic Cape Sugarbird (*Promerops cafer*). In general, and predictably, omnivores are among the least affected by plant invasions (e.g. Macdonald & Richardson 1986; Fraser 1990a).

Extent of invasions across biomes

Biological invaders have affected native birds in all the eight major biomes in Africa (Fig. 11, Table 3). In four of these biomes (Mediterranean forests, woodlands, and scrub forests; deserts and xeric shrublands; tropical and subtropical grasslands, savannas, and shrublands; and montane grasslands and shrublands), invaders have negatively impacted more than 100 native bird species, with shrublands and montane grasslands being the most impacted biomes (Table 3).

Montane grasslands and shrublands cover extensive areas in Africa (http://www.panda.org/about_our_earth/ecoregions) with the result that invasions in these areas are expected to affect a large number of native birds. The conservation status of some of the montane areas is rated critical or endangered. For example, the Southern Rift montane forest-grassland mosaic is rated *Critically Endangered*, with biological invasions being one of the main contributing factors (http://www.panda.org/about_our_earth/ecoregions/).

Biomes comprising motane, tropical and subtropical grasslands, shrublands, woodlands and forests generally ranked high among the biomes experiencing negative effects of invasive species on native birds (Fig. 11, Table 3). These have also been identified as biomes experiencing extensive biological invasions (Richardson & van Wilgen 2004; van Wilgen et al. 2008). For example, in Mpumalanga Province, South Africa, at least 90 species of grassland birds are affected by invasive plantation trees (Allan et al. 1997). In pastoral areas of Uganda, birds associated with grasslands are negatively affected by grazing (Asasira & Pomeroy 2008).

Based on this review, our knowledge of the impact of alien invasive grasses on native birds in Africa is poor –a deficiency noted previously (Milton 2004). Grasslands are identified here as one of the biomes experiencing the greatest negative effects from invaders, especially plant invaders.

There is one important caveat in this analysis of the geographical extent of these impacts, namely a bias towards studies made in southern Africa, especially South Africa. This almost certainly stems from a bias in research effort rather than southern Africa being disproportionally impacted by invasive species. There are other major invasives in Africa, such as the *Prosopis* invasion of central Kenya, whose biological impacts remain unquantified for birds.

Emerging issues and challenges

Africa has been identified as the continent potentially most at risk from the negative effects of climate change on biodiversity (IPCC 2001). The IPCC (2001) predicts that some of the effects of global change in Africa include increased average seasonal temperatures, decreases in rainfall in most areas, and an increased frequency and severity of weather anomalies (Boko et al. 2007). These changes are expected to affect native birds (e.g. see Midgley et al. 2001; Erasmus et al. 2002; Berthold et al. 2004; Simmons et al. 2004; Barnard & Simmons, 2009; Hockey & Midgley 2009). Predictably, if the invasive birds will also expand their range as a result of climate change, their impacts on native birds may become more widespread. For example, the predicted range expansion of the House Crow beyond its current distribution to parts of western Africa (Nyári et al. 2006) may be expected to affect more native birds in those areas.

Several emerging infectious diseases are invasive and pose particular threats to native birds globally (BirdLife International 2008). Outbreaks of invasive pathogens such as Avian Cholera (*Pasteurella multocida*) continue to cause significant mortality to native birds in Africa. Avian botulism is another invasive and fatal disease in birds. Controlling these invasive diseases and pathogens is a significant challenge for the future.

Another challenge is the appearance of new invaders, especially in the form of native species that suddenly increase in abundance and extend their ranges, thereby becoming novel components in communities/ecosystems. For example, among the invasive plants in Northern Africa (<200 species) *ca* 133 species are native (Floc'h et al. 1990). Emerging plant invaders have also been reported in South Africa (Nel et al. 2004). Several native birds have also expanded their ranges in parts of Africa (Macdonald 1986, 1990; Hockey 2003, Hockey et al. in review) and should perhaps be also considered to be invasive (although not introduced) because of their potential negative consequences on other native birds (Hockey 2003).

Conclusion

Although invasive species affect native birds in Africa both positively (191 species) and negatively (572 species), it is the negative impacts that are dominant, lending support to the widely held view that biological invasions are eroding native biodiversity (e.g. Vitousek et al. 1997). Fortunately, mainland Africa has not recorded any extinction of native birds from biological invasions (Hockey 2009a).

Some generalizations can be made about the patterns of these impacts. For example, the majority of impacts stem from structural changes in habitats and

resource availability to native birds: invertebrate-feeding species are disproportionally heavily impacted, and impacts are greatest in grassland and shrubland biomes.

It can be predicted that native birds will continue to lose more than they gain as a consequence of biological invasions. The fact that these impacts affect some functional guilds disproportionately more than others implies that these impacts will be greater than simply taxonomic. They are also likely to be exacerbated by two other key factors that are causing distributional changes among native birds, namely climate change and anthropogenic landscape-level change (Parmesan & Yohe 2003; Root et al. 2003, Hockey & Midgely 2009, Hockey et al. in review).

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APPENDICES

Appendix 1: List of native birds negatively affected by invasive species.

Numbers represent: 0= not affected, 1=affected.

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
Accipiter badius	1	0	0	0	0
A. minullus	1	0	0	0	1
Actophilornis africanus	0	0	0	1	0
Aegypius tracheliotos	0	0	0	1	0
Agapornis nigrigenis	0	1	0	0	0
A. personata	0	0	0	0	1
A. roseicollis	1	0	0	0	0
Agopornis taranta	0	1	0	0	0
Alcedo semitorquarta	1	0	0	0	0
Alseonax adusta	1	0	0	0	0
Amazona sp.	0	1	0	0	0
Amblyospiza albifrons	1	0	0	0	1
Anas capensis	1	0	0	0	0
Anas clypeata	1	0	0	0	0
A. erythrorhyncha	1	0	0	0	0
A. penelope	1	0	0	0	0
A. sparsa	1	0	0	0	1
A. undulata	0	0	0	0	1
Andropadus ansorgei	1	0	0	0	0
A. importunus	1	0	0	0	0
A. tephrolaemus	1	0	0	0	0
Anomalospiza imberbis	1	0	0	1	0
Anthreptes pallidigaster	1	0	0	0	0
A. reichenowi	1	0	0	0	0
Anthobaphes violacea	1	0	0	0	0
Anthoscopus minutus	0	0	0	1	0
A. collaris	1	0	0	0	1
A. neglectus	1	0	0	0	0
Anthropoides paradiseus	1	0	0	0	0
Anthus brachyurus	1	0	0	0	0
A. chloris	1	0	0	1	0
A. cinnamomeus	1	0	0	1	0
A. crenatus	1	0	0	1	0
A. hoeschi	1	0	0	0	0
A. leucophrys	1	0	0	0	0
A. similis	1	0	0	1	0
A. sokokensis	1	0	0	0	0
A. vaalensis	1	0	0	1	0
Apalis caniceps	1	0	0	0	0
A. chariessa	1	0	0	0	0
A. flavida	1	0	0	0	0

Appendix 1 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
A. flavigularis	1	0	0	0	0
A. karamojae	0	0	0	1	0
A. melanocephala	1	0	0	0	0
A. moreaui	1	0	0	0	0
A. porphyrolaema	1	0	0	0	0
A. sharpii	1	0	0	0	0
A. thoracica	1	0	0	0	0
Apaloderma narina	1	0	0	0	0
A. vittatum	1	0	0	0	0
Aplopelia larvata	1	0	0	0	0
Apus affinis	0	0	0	1	0
A. barbatus	0	0	0	1	0
A. bradfieldi	0	0	0	1	0
A. caffer	1	0	0	0	1
Aquila rapax	1	0	0	1	0
A. verreauxii	0	0	0	1	0
A. wahlbergi	0	0	0	0	1
Ara macao	0	1	0	0	0
Aratinga sp.	0	1	0	0	0
Ardea cinerea	0	0	0	0	1
A. melanocephala	1	0	0	0	1
Ardeotis kori	1	0	0	1	0
Argya rubiginosa	0	0	0	0	1
Asio capensis	1	0	0	1	0
Aviceda cuculoides	1	0	0	0	0
Baepogon indicator	1	0	0	0	0
Balaeniceps rex	0	0	0	1	0
Balearica pavonina	1	0	0	0	0
B. regulorum	1	0	0	1	0
Bathmocercus winifredae	1	0	0	0	0
Batis batis	1	0	0	0	0
B. capensis	1	0	0	0	0
B. mixta	1	0	0	0	0
B. molitor	0	0	0	1	0
B. pririt	1	0	0	1	0
B. soror	1	0	0	0	0
Bostrychia hagedash	1	0	0	1	1
B. olivacea	0	0	0	1	0
Botaurus stellaris	0	0	0	1	0
Bradornis pallidus	0	0	0	1	0
Bradypterus carpalis	1	0	0	1	0
B. cinnamomeus	1	0	0	0	0
Breda syndactyla	1	0	0	0	0
Bubalornis niger	1	0	0	0	0

Appendix 1 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
Bubo vosseleri	1	0	0	0	0
Bucorvus leadbeateri	1	0	0	1	0
Bugeranus carunculatus	1	0	0	1	0
Buphagus erythrorhynchus	0	0	0	1	0
Burhinus capensis	0	0	0	1	0
Butastus rufipennis	1	0	0	0	0
Buteo buteo	1	0	0	1	0
B. rufofuscus	1	0	0	0	0
Bycanistes brevis	1	0	0	0	0
B. bucinator	1	0	0	0	0
Cacatua alba	0	1	0	0	0
Calandrella cinerea	1	0	0	1	0
Calendulauda africanoides	1	0	0	0	0
C. fulvicapilla	1	0	0	0	0
Calidris ferruginea	0	0	0	0	1
C. minuta	0	0	0	0	1
Camaroptera brachyla	1	0	0	0	0
C. sp.	0	0	0	0	1
Campethera abingoni	1	0	0	0	0
C. cailliautii	1	0	0	0	0
Caprimulgus pectoralis	1	0	0	0	0
Centropus grillii	1	0	0	0	0
Cercomela schlegelli	0	0	0	1	0
C. sinuata	0	0	0	1	0
C. tractrac	0	0	0	1	0
Cercotricas coryphaeus	0	0	0	1	0
C. quadrivirgata	1	0	0	0	0
Cercotrichas coryphaeus	1	0	0	0	0
C. paena	1	0	0	0	0
Certhilauda burra	0	0	0	1	0
C. albescens	0	0	0	1	0
C. curvirostris	0	0	0	1	0
Ceryle rudis	0	0	1	0	1
Ceuthmochares aereus	1	0	0	0	0
Chaetops aurantius	1	0	0	0	0
Chalcomitra amethystina	1	0	0	0	0
C. senegalensis	1	0	0	0	0
Chersomanes albofasciata	1	0	0	1	0
Chlidonias hybridus	1	0	0	0	0
C. leucopterus	1	0	1	0	0
Chlorocichla flaviventris	1	0	0	0	0
C. prigoginei	1	0	0	0	0
Chloropeta gracilirostris	1	0	0	1	0
C. natalensis	1	0	0	0	0
C. similis	1	0	0	0	0

Appendix 1 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
Chloroptera natalensis	1	0	0	0	0
Chrysococcyx caprius	1	0	0	0	0
Ciccaba woodfordii	1	0	0	0	0
Cichladusa arquata	0	0	0	0	1
C. guttata	0	0	0	0	1
Ciconia ciconia	1	0	0	1	0
C. episcopus	0	0	0	0	1
C. nigra	1	0	0	0	0
Cinnyricinclus femoralis	0	0	0	1	0
Cinnyris chalybeus	1	0	0	0	0
C. reichenowi	1	0	0	0	0
C. talatala	1	0	0	0	0
Circaetus cinereus	0	0	0	1	0
C. fasciolatus	1	0	0	0	0
C. pectoralis	0	0	0	0	1
Circus aeruginosus	0	0	0	0	1
C. macrourus	1	0	0	1	0
C. maurus	1	0	0	1	0
C. pygargus	1	0	0	0	0
C. ranivorus	1	0	0	0	0
Cisticola aberdare	0	0	0	1	0
C. aridula	1	0	0	0	0
C. ayresii	1	0	0	1	0
C. brunnescens	1	0	0	1	0
C. cantans	1	0	0	0	0
C. carruthersi	1	0	0	1	0
C. chiniana	0	0	0	1	0
C. fulvicapilla	1	0	0	0	0
C. hunteri	1	0	0	0	0
C. juncidis	1	0	0	0	0
C. lais	1	0	0	0	0
C. natalensis	1	0	0	0	0
C. subruficapilla	1	0	0	1	0
C. textrix	1	0	0	0	0
C. tinniens	1	0	0	1	0
Clamator jacobinus	0	0	0	0	1
Coccopygia melanotis	1	0	0	0	0
Colius colius	1	0	0	0	0
C. indicus	1	0	0	0	0
C. spp.	0	0	0	0	1
C. striatus	1	0	0	0	1
Columba aquartrix	1	0	0	0	1
C. delegorguei	1	0	0	0	0
Coracias caudata	1	0	0	0	0
C. caesia	1	0	0	0	0

Appendix 1 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
C. caudata	0	0	0	0	1
Corvus albicollis	1	0	0	1	0
C. albus	1	0	0	0	1
C. capensis	1	0	0	1	0
C. corone sardonicus	0	1	0	0	1
Corythaeola cristata	1	0	0	0	0
Corythaixoides concola	1	0	0	0	0
Cossypha caffra	1	0	0	0	0
C. dichroa	1	0	0	0	0
C. heuglini	1	0	0	0	1
C. humeralis	1	0	0	0	0
Coturnix adansonii	0	0	0	1	0
C. coturnix	1	0	0	1	0
Crex crex	1	0	0	0	0
Crithagra albogularis	1	0	0	1	0
C. atrogularis	0	0	0	1	0
C. flaviventris	1	0	0	1	0
C. koliensis	0	0	0	1	0
C. leucopterus	1	0	0	0	0
C. mozambicus	1	0	0	1	0
C. symonsi	1	0	0	0	0
Cryptospiza salvadorii	1	0	0	0	0
Cuculus solitarius	1	0	0	0	0
Cypsiusrus parva	0	0	0	0	1
Dendrocygna bicolor	1	0	0	0	0
Dendropicos fuscescens	1	0	0	0	0
Dicrurus adsimilis	0	0	0	1	1
D. atripennis	1	0	0	0	0
Dioptrornis fischeri	1	0	0	0	0
D. ludwigii	1	0	0	0	0
Dryoscopus cubla	1	0	0	0	1
Eclectus roratus	0	1	0	0	0
Egretta alba	0	0	0	1	0
Elanus axillaris	0	0	0	1	0
E. caeruleus	1	0	0	0	1
Emberiza capensis	1	0	0	1	0
E. impetuani	0	0	0	1	0
Ephippiorhynhus senegalensis	0	0	0	1	0
Erannornis longicauda	1	0	0	0	0
Eremomela gregalis	0	0	0	1	0
Eremopterix australis	0	0	0	1	0
E. verticalis	0	0	0	1	0
Erythropygia leucophrys	1	0	0	0	0
Estrilda astrild	0	0	0	1	0
E. erythronotos	1	0	0	0	0

Appendix 1 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
Euplectes afer	1	0	0	1	0
E. albonotatus	1	0	0	0	0
E. ardens	0	0	0	1	0
E. axillaris	1	0	0	0	0
E. capensis	1	0	0	0	0
E. nigroventris	0	0	0	0	1
E. orix	1	0	0	1	0
E. progne	1	0	0	1	0
Eupodotis afra	1	0	0	1	0
E. caerulescens	1	0	0	1	0
E. melanogaster	1	0	0	0	0
E. senegalensis	1	0	0	0	0
E. vigorsii	0	0	0	1	0
Euryptila subcinnamonea	0	0	0	1	0
Falco amurensis	1	0	0	0	0
F. biarmicus	1	0	0	0	0
F. cuvierii	1	0	0	0	0
F. naumanni	1	0	0	0	0
F. peregrinus	1	0	0	0	0
F. rupicoloides	1	0	0	0	0
F. rupicolus	1	0	0	0	0
F. subbuteo	1	0	0	0	0
F. tinnunculus	1	1	0	0	0
Fraseria ocreata	1	0	0	0	0
Fulica cristata	1	0	1	0	0
Galerida magnirostris	0	0	0	1	0
Gallinula chloropus	1	0	0	0	0
Geocolaptes olivaceus	1	0	0	1	0
Geronticus calvus	1	0	0	1	0
Glareola nordmanni	1	0	0	0	0
Glaucidium tephronotum	0	0	0	1	0
Grus carunculatus	1	0	0	0	0
G. grus	1	0	0	0	0
Guttera pucherani	1	0	0	0	0
Gymnobucco calvus	1	0	0	0	0
Gypaetus barbatus	1	0	0	0	0
Gypohierax angolensis	1	0	0	0	0
Gyps africanus	0	0	0	1	0
G. coprotheres	0	0	0	1	0
Halcyon senegaloides	0	0	0	0	1
Haliaeetus vocifer	0	0	0	1	1
Hemimacronyx chloris	1	0	0	0	0
Heteromirafra ruddi	1	0	0	1	0
H. dubius	1	0	0	0	0
H. ayresii	0	0	0	1	0
Hirundo abyssinica	0	0	0	0	1

Appendix 1 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
H. atrocaerulea	1	0	0	0	0
H. cucullata	1	0	0	0	0
H. fuligula	0	0	0	1	0
H. rustica	1	0	0	0	0
H. semirufa	1	0	0	0	0
H. spilodera	1	1	0	0	1
Hylia prasina	1	0	0	0	0
Illadopsis rufescens	1	0	0	0	0
Indicator indicator	1	0	0	0	0
I. narokensis	1	0	0	0	0
I. variegatus	1	0	0	0	0
Ispidina picta	1	0	0	0	0
Jynx ruficollis	0	0	0	0	1
Kaupifalco monogrammicus	1	0	0	0	1
Lagonostica rubricata	1	0	0	0	0
Lamprotornis australis	0	0	0	1	0
L. corruscus	1	0	0	0	0
L. nitens	1	0	0	0	0
Laniarius aethiopicus	1	0	0	0	0
L. ferrugineus	1	0	0	0	0
L. funebris	0	0	0	1	0
L. mufumbiri	1	0	0	1	0
L. sp.	1	0	0	0	0
Lanius collaris	1	0	0	0	0
Larus cirrocephalus	1	0	1	0	0
L. dominicanus	0	1	0	0	0
L. fuscus	0	0	1	0	0
L. hartlaubii	0	1	0	0	0
L. hemprichii	0	0	0	0	1
Leptoptilos crumeniferus	0	0	0	1	0
Lonchura cucullatus	0	0	0	0	1
Lophaetus occipitalis	1	0	0	0	0
Luscinia luscinia	1	0	0	0	0
Macheiramphus alcinus	1	0	0	0	0
Macronyx ameliae	1	0	0	0	0
M. capensis	1	0	0	1	0
Malaconotus alius	1	0	0	0	0
Malcorus pectoralis	0	0	0	1	0
Mandingoa nitidula	1	0	0	0	0
Melierax canorus	1	0	0	0	1
Melopsittacus undulatus	0	1	0	0	0
Merops apiaster	0	0	0	0	1
Mesopicos griseocephalus	1	0	0	0	0
Microparra capensis	1	0	0	0	0
Milvus migrans	0	0	1	1	1

Appendix 1 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
M. sp.	0	1	0	0	0
Mirafra africana	1	0	0	0	0
M. apiata	1	0	0	0	0
M. curvirostris	1	0	0	1	0
Moniticola explorator	1	0	0	1	0
Morus capensis	0	1	0	0	0
Motacilla capensis	1	0	0	1	1
Muscicapa adusta	1	0	0	0	0
M. caerulescens	1	0	0	0	0
M. olivascens	1	0	0	0	0
M. striata	1	0	0	0	0
M. ussheri	1	0	0	0	0
Myoparus plumbeus	1	0	0	0	0
Myrmecocichla arnoti	0	0	0	1	0
M. formicivora	1	0	0	0	0
Neafrapus boehmi	1	0	0	0	0
Nectarinia afra	1	0	0	0	0
N. amethystina	1	0	0	0	0
N. chalybea	0	0	0	1	0
N. erythrocerca	1	0	0	0	0
N. famosa	1	0	0	1	0
N. fusca	0	0	0	1	0
N. kilimensis	1	0	0	0	0
N. loveridgei	1	0	0	0	0
N. olivacea	2	0	0	0	0
N. senegalensis	0	0	0	0	1
N. tacazze	1	0	0	0	0
Neocossyphus poensis	1	0	0	0	0
N. rufus	1	0	0	0	0
Neophron percnopterus	0	0	0	1	0
Neotis denhami	1	0	0	1	0
N. ludwigit	0	0	0	1	0
Netta erythrophthalma	0	0	0	0	1
Nicator chloris	1	0	0	0	0
Nilaus afer	1	0	0	0	0
Numida meleagris	1	0	0	1	0
Oena capensis	1	0	0	1	0
Oenanthe bifasciata	1	0	0	1	0
O. monticola	0	0	0	1	0
O. pileata	1	0	0	0	0
Onychognathus morio	1	0	0	0	1
O. nabouroup	0	0	0	1	0
Oriolus auratus	0	0	0	0	1
O. chlorocephalus	1	0	0	0	0
O. larvatus	1	0	0	0	0

Appendix 1 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
O. oriolus	0	0	0	0	1
O. brachyrynchus	1	0	0	0	0
Orthotomus metopias	1	0	0	0	0
Ortygospiza atricollis	1	0	0	1	0
Othyphantes reichenowi	1	0	0	0	0
Otus ireneae	1	0	0	0	0
O. senegalensis	0	0	0	1	0
Oxyura leucocephala	1	0	1	0	1
O. maccoa	0	0	0	0	1
Paccycoccyx audeberti	1	0	0	0	0
Parisoma boehmi	0	0	0	1	0
P. layardi	1	0	0	1	0
Parus afer	0	0	0	1	0
P. cinerascens	1	0	0	0	0
Passer castanopterus	0	0	0	0	1
P. diffusus	0	0	0	0	1
P. griseus	0	0	0	0	1
P. guinea	0	0	0	0	1
P. melanurus	1	0	0	0	1
Pelecanus rufescens	0	0	1	0	0
Pernis apivorus	1	0	0	0	0
Phalacrocorax africanus	0	0	1	0	0
P. capensis	0	1	0	0	0
P. carbo	0	0	1	0	0
P. sp.	0	0	1	0	0
Pheoniculus purpureus	1	0	0	0	0
Phoenicopterus rubber	1	0	0	0	0
P. cyanomelus	1	0	0	0	0
P. purpureus	0	0	0	0	1
Phragmacia substriata	0	0	0	1	0
Phyllanthus atripennis	1	0	0	0	0
Phyllastrephus debilis	1	0	0	0	0
P. fischeri	1	0	0	0	0
P. icterinus	1	0	0	0	0
P. terrestris	1	0	0	0	0
Phylloscopus ruficapillus	1	0	0	0	0
P. trochilus	1	0	0	1	0
P. umbrovirens	1	0	0	0	0
Pionites leucogaster	0	1	0	0	0
Pitta angolensis	1	0	0	0	0
Plectropterus gambensis	0	0	0	1	0
Ploceus bicolar	1	0	0	0	0
P. bojeli	0	0	0	0	1
P. capensis	1	0	0	1	0
P. castanops	1	0	0	0	0

Appendix 1 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
P. cucullatus	0	0	0	0	1
P. golandi	1	0	0	0	0
P. intermedius	0	0	0	0	1
P. ocularis	1	0	0	0	0
P. velatus	0	0	0	0	1
P. xanthops	1	0	0	0	1
Podica senegalensis	1	0	0	0	0
Pogoniulus atroflavus	1	0	0	0	0
P. scolopaceus	1	0	0	0	0
P. simplex	1	0	0	0	0
P. subsulphureus	1	0	0	0	0
Pogonocichla stellata	1	0	0	0	0
Poicephalus gulielmi	0	1	0	0	0
P. robustus	0	1	0	0	0
P. rueppellii	0	1	0	0	0
P. rufiventris	0	1	0	0	0
P. senegalus	0	1	0	0	0
Polemaetus bellicosus	0	0	0	1	0
Polyboroides radiatus	1	0	0	0	0
P. typus	1	0	0	1	0
Porzana pusilla	1	0	0	0	0
Prinia hypoxantha	1	0	0	1	0
P. maculosa	1	0	0	1	0
P. subflava	1	0	0	0	0
Prionops retzii	1	0	0	0	0
P. scopifrons	1	0	0	0	0
Prodotiscus zambesiae	1	0	0	0	0
Promerops cafer	1	0	0	0	0
P. gurneyi	1	0	0	1	0
Psalidoprocne pristoptera	1	0	0	0	0
P. holomelaena	1	0	0	0	0
P. holomelus	1	0	0	0	0
Psittacus erithacus	0	1	0	0	0
Pternistis adspersus	1	0	0	1	0
P. capensis	1	0	0	0	0
P. natalensis	1	0	0	0	0
P. swainsonii	0	0	0	1	0
Pterocles bicincutus	1	0	0	0	0
P. namaqua	0	0	0	1	0
Pycnonotus barbatus	1	0	0	1	1
P. capensis	1	0	0	1	1
P. nigricans	1	0	0	0	0
P. xanhopugos	1	0	0	0	0
Rhinopomastus cyanomelas	1	0	0	0	0
Rhinoptilus chalcopterus	1	0	0	0	0

Appendix 1 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
Riparia cincta	1	0	0	1	0
Rostratula benghalensis	1	0	0	0	0
Rynchops flavirostris	0	0	1	0	0
Sagittarius serpentarius	1	0	0	1	0
Sarothrura affinis	1	0	0	0	0
S. ayresi	1	0	0	0	0
Saxicola torquata	1	0	0	1	0
Schoenicola brevirostris	1	0	0	1	0
Scleroptila africanus	1	0	0	0	0
S. africanus	1	0	0	0	0
S. levaillantii	1	0	0	1	0
S. levaillantoides	1	0	0	1	0
Scopus umbretta	0	0	1	0	0
Seicercus umbroirens	1	0	0	0	0
Serinus alario	1	0	0	1	0
S. atrogularis	1	0	0	0	0
S. burtoni	1	0	0	0	0
S. canicollis	1	0	0	1	0
S. citrinelloides	1	0	0	0	0
S. flaviventris	1	0	0	0	0
S. gularis	1	0	0	0	0
S. koliensis	1	0	0	0	0
S. mozambicus	1	0	0	0	0
S. striolatus	1	0	0	0	0
S. sulphuratus	1	0	0	0	0
S. totta	1	0	0	0	0
Sheppardia aequatorialis	1	0	0	0	0
S. cyornithopis	1	0	0	0	0
Sitta ledanti	0	0	0	1	0
Spheniscus demersus	1	0	0	0	0
Sphenoeacus afer	1	0	0	0	0
Spizocorys conirostris	1	0	0	1	0
S. fringillaris	1	0	0	0	0
S. sclateri	0	0	0	1	0
Sporaeginthus subflavus	1	0	0	0	0
Spreo bicolor	1	0	0	0	0
Stelgidocichla latirostris	1	0	0	0	0
Stenpstira scita	0	0	0	1	0
Stephanoaetus coronatus	1	0	0	1	0
Sterna balaenarum	1	0	0	0	0
S. bergii	0	1	0	0	0
S. nilotica	1	0	0	0	0
Stiphrornis erythrothrorax	1	0	0	0	0
Streptopelia capicola	1	1	0	1	0
S. luges	1	0	0	0	0

Appendix 1 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
S. semitorquata	1	0	0	0	1
S. senegalensis	1	1	0	1	1
Struthio camerus	0	0	0	1	0
Sylvia communis	1	0	0	0	0
Sylvietta rufescens	1	0	0	0	0
Tadorna tadorna	1	0	0	0	0
Tauraco colythaix	1	0	0	0	0
T. porphyreolophus	1	0	0	0	0
Tchagra australis	1	0	0	0	0
T. tchangra	1	0	0	0	0
Telephorus quadricolor	1	0	0	0	0
T. zeylonus	1	0	0	0	0
T. olivaceus	1	0	0	0	0
Terathopius ecaudatus	0	0	0	1	0
Terpsiphone viridis	1	0	0	0	0
Threskiornis aethiopicus	0	1	0	0	0
T. sp.	0	0	1	0	0
Tockus alboterminatus	1	0	0	0	0
T. fasciatus	1	0	0	0	0
T. leucomelas	1	0	0	0	0
Trachyphonus sp.	1	0	0	0	0
T. vaillantii	1	0	0	0	1
Treron australis	1	0	0	0	0
Trichoglossus sp.	0	1	0	0	0
Tricholaema leucomelas	1	0	0	0	0
Turdoides sharpei	1	0	0	0	0
Turdus libonyana	1	0	0	0	0
T. litsitsirupa	1	0	0	0	0
T. olivaceus	1	1	0	0	0
T. piaggiae	1	0	0	0	0
T. smithi	1	0	0	0	1
Turnix hottentotta	1	0	0	0	0
T. sylvatica	1	0	0	1	0
Turtur chalcospilosis	1	0	0	0	0
T. tymapnistria	1	0	0	0	0
Tyto alba	1	0	0	0	0
T. capensis	1	0	0	1	0
Upupa africana	0	0	0	0	1
U. epops	0	0	0	0	1
Uraeginthus bengalus	0	0	0	0	1
U. granatinus	1	0	0	0	0
U. ianthinogaster	0	0	0	1	0
Urocolius indicus	1	0	0	0	0

Appendix 1 Continued

Vanellus albiceps	1	0	0	0	0
V. coronatus	1	0	0	1	0
V. melanopterus	1	0	0	0	0
V. senegallus	1	0	0	0	0
Vidua macroura	0	0	0	1	0
V. regia	1	0	0	0	0
Xanthophilus capensis	1	0	0	0	0
Zosterops kikyuensis	1	0	0	0	0
Z. pallidus	1	0	0	0	0
Z. virens	1	0	0	0	0
Grand Total	**397**	**29**	**14**	**154**	**74**

Appendix 2: List of native birds benefiting from invasive species.

Numbers represent: 0= did not benefit, 1= benefited.

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
Accipiter badius	1	0	0	0	0
A. rufiventris	0	0	0	1	0
Actophilornis africanus	1	0	0	0	0
Agapornis fischeri	1	0	0	0	0
Alopochen aegyptiacus	1	0	0	0	0
Amadina fasciata	1	0	0	0	0
Amblyospiza albiflons	1	0	0	0	0
Anas erythrorhyncha	1	0	0	0	0
A. sparsa	1	0	0	0	0
Andropadus importunus	1	0	0	0	0
Anhinga rufa	0	0	1	0	0
Anthropoides paradiseus	0	0	0	1	0
Anthus cinnamomeus	0	0	0	1	0
A. leucophrys	0	0	0	1	0
Apalis flavida	1	0	0	0	0
A. thoracica	1	0	0	0	0
Apus apus	1	0	0	0	0
Aquila rapax	0	0	0	1	0
A. verreauxii	0	0	0	1	0
A. wahlbergi	1	0	0	0	0
Ardea melanocephala	1	0	0	0	0
Balaenceps rex	1	0	0	0	0
Bostrychia hagedash	1	0	0	0	0
Bradornis mariquensis	0	0	0	1	0
Bradypterus sylvaticus	1	0	0	0	0
Burhinus capensis	1	0	0	0	0
Buteo buteo	0	0	0	1	0
B. rufofuscus	0	0	0	1	0
Calandrella cinerea	0	0	0	1	0
Ceratogymna atrata	1	0	0	0	0
C. cylindricus	1	0	0	0	0
Cercomela familiaris	1	0	0	0	0
C. schlegelli	0	0	0	1	0
Cercotrichas coryphaeus	1	0	0	0	0
C. paena	0	0	0	1	0
Ceryle rudis	0	0	1	0	0
Charadrius pecuarius	0	0	0	1	0
Chlidonias leucoptera	0	0	1	0	0
Chloropeta natalensis	1	0	0	0	0

Appendix 2 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
Chrysococcyx caprius	0	0	0	1	0
Cinnyris chalybeus	1	0	0	0	0
C. mariquensis	0	0	0	1	0
Circaetus cinereus	1	0	0	1	0
C. pectoralis	0	0	0	1	0
Circus aeruginosus	1	0	0	0	0
C. ranivorus	0	0	0	1	0
Cisticola erythrops	1	0	0	0	0
C. fulvicapilla	1	0	0	0	0
Clamator jacobinus	1	0	0	0	0
Colius colius	1	0	0	0	0
C. indicus	1	0	0	0	0
C. striatus	1	0	0	0	0
Columba guinea	1	0	0	0	0
Corvus albicollis	1	0	0	0	0
C. albus	1	0	0	0	0
C. capensis	1	0	0	0	0
Corythaixoides concolor	1	0	0	0	0
Cossypha caffra	1	0	0	0	0
Creatophora cinerea	1	0	0	0	0
Crithagra albogularis	1	0	0	0	0
C. flaviventris	1	0	0	0	0
C. mozambicus	1	0	0	0	0
Cuculus gularis	1	0	0	0	0
C. solitarius	1	0	0	0	0
Dicrurus adsimilis	1	0	0	0	0
D. sp.	1	0	0	0	0
Dryoscopus cubla	1	0	0	0	0
Egretta garzetta	1	0	0	0	0
Elanus axillaris	0	0	0	1	0
E. caeruleus	1	0	0	0	0
Emberiza capensis	1	0	0	0	0
Estrilda astrild	1	0	0	0	0
Euplectes capensis	1	0	0	0	0
E. orix	1	0	0	0	0
Eupodotis afra	1	0	0	0	0
E. ruficrista	1	0	0	0	0
Euryptila subcinnamonea	0	0	0	1	0
Falco amurensis	0	0	0	1	0
F. ardosiaceus	1	0	0	0	0
F. biarmicus	1	0	0	1	0

Appendix 2 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
F. naumanni	1	0	0	1	0
F. rupicoloides	0	0	0	1	0
Fulica cristata	1	0	0	0	0
Galerida magnirostris	0	0	0	1	0
Gallinula chloropus	1	0	0	0	0
Geronticus calvus	0	0	0	1	0
Gyps africanus	0	0	0	1	0
G. coprotheres	0	0	0	1	0
Haematopus moquini	0	1	0	0	0
Haliaeetus vocifer	1	0	1	0	0
Hedydipna collaris	1	0	0	0	0
Heteromirafra ruddi	0	0	0	1	0
H. fasciatus	1	0	0	0	0
Hirundo rustica	1	0	0	0	0
Hypochera chalybeata	1	0	0	0	0
Lagonostica senegala	1	0	0	0	0
Lamprotornis nitens	1	0	0	1	0
L. superbus	0	0	0	1	0
Laniarius ferrugineus	1	0	0	0	0
L. atrococcineus	0	0	0	1	0
Lanius collaris	1	0	0	0	0
Larus cirrocepharus	0	0	1	0	0
L. fuscus	0	0	1	0	0
Melierax canorus	0	0	0	1	0
M. gabar	1	0	0	0	0
Milvus migrans	1	0	1	0	0
Mirafra africanoides	1	0	0	0	0
M. sabota	1	0	0	1	0
Motacilla capensis	1	0	0	0	0
M. clara	0	0	0	1	0
Myrmecocichla formicivora	0	0	0	1	0
Nectarinia famosa	1	0	0	0	0
Nettapus auritus	1	0	0	0	0
Numida meleagris	1	0	0	0	0
N. mitrata	1	0	0	0	0
Oena capensis	1	0	0	0	0
Onychognathus morio	1	0	0	0	0
Oriolus oriolus	1	0	0	0	0
O. sp.	1	0	0	0	0
Oxyura leucocephala	1	0	0	0	0
Parisoma layardi	0	0	0	1	0

Appendix 2 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
Passer melanurus	1	0	0	0	0
P. melanus	0	0	0	1	0
Pelecanus rufescens	0	0	1	0	0
Phalacrocorax africanus	0	0	1	0	0
P. carbo	0	0	1	0	0
P. sp.	0	0	1	0	0
Plocepasser mahali	0	0	0	1	0
Ploceus capensis	1	0	0	0	0
P. cucullatus	1	0	0	0	0
P. luteolus	1	0	0	0	0
P. ocularis	1	0	0	0	0
P. ruweti	1	0	0	0	0
P. velatus	1	0	0	1	0
P. xanthops	1	0	0	0	0
Polemaetus bellicosus	0	0	0	1	0
Prinia flavicans	0	0	0	1	0
P. maculosa	1	0	0	0	0
P. subflava	1	0	0	1	0
Promerops caffer	1	0	0	0	0
P. sp.	1	0	0	0	0
Pternis apivorus	0	1	0	0	0
Pternistis capensis	1	0	0	0	0
Pterocles bicinctus	1	0	0	0	0
Pycnonotus barbatus	1	0	0	0	0
P. capensis	1	0	0	0	0
P. nigricans	1	0	0	1	0
P. tricolor	1	0	0	0	0
Sagittarius serpentarius	0	0	0	1	0
Scleroptila africanus	0	0	0	1	0
Scopus umbretta	0	0	1	0	0
Serinus alario	1	0	0	0	0
S. canicollis	1	0	0	0	0
S. sulphuratus	1	0	0	0	0
Sigelus silens	1	0	0	0	0
Spenoeacus afer	0	0	0	1	0
Spermestes fringilloides	1	0	0	0	0
Spheniscus demersus	1	0	0	0	0
Spizocorys fringillaris	0	0	0	1	0
Spreo bicolor	1	0	0	0	0
Streptopelia capicola	1	0	0	1	0
S. semitorquata	1	0	0	0	0
S. senegalensis	1	0	0	1	0

Appendix 2 Continued

Species	Invasive plants	Invasive invertebrates	Invasive fish	Invasive mammals	Invasive birds
Sylvietta rufescens	1	0	0	0	0
Tauraco porphyreolophus	1	0	0	0	0
Telophorus zeylonus	1	0	0	1	0
Terathopius ecaudatus	0	0	0	1	0
Terpsiphone viridis	1	0	0	0	0
Threskiornis sp.	0	0	1	0	0
Treron australis	1	0	0	0	0
Tricholaema leucomelas	1	0	0	1	0
Trochocercus cyanomelas	1	0	0	0	0
Turdoides bicolar	0	0	0	1	0
T. hindei	1	0	0	0	0
Turdus libonyana	1	0	0	0	0
T. litsitsirupa	0	0	0	1	0
T. olivaceus	1	0	0	0	0
T. smithi	1	0	0	0	0
Upupa africana	1	0	0	0	0
U. epops	0	0	0	1	0
Urocolius indicus	1	0	0	0	0
Vanellus armatus	1	0	0	0	0
V. coronatus	1	0	0	0	0
V. crassirostris	1	0	0	0	0
V. melanopterus	0	0	0	1	0
Vidua macroura	1	0	0	0	0
Xanthophilus capensis	1	0	0	0	0
Zosterops capensis	1	0	0	0	0
Z. pallidus	1	0	0	0	0
Z. sp.	1	0	0	0	0
Grand Total	**132**	**2**	**13**	**57**	**0**