Cranes and crops: investigating the viability of Blue Cranes in agricultural lands of the Western Cape

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Minor dissertation in partial fulfilment of the requirements for the degree of
Master of Science in Conservation Biology
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February 2016

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed are those of the author and are not necessarily to be attributed to the NRF.

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Acknowledgments

I am very grateful to all those who assisted with this project. Firstly, to my supervisor Professor Peter Ryan for his encouragement and sage advice. Your ability to make time for me regardless of circumstances was much appreciated. To my co-supervisor Tanya Smith from the endangered Wildlife Trust (EWT) for her helpful comments and Dr. Res Altwegg, who provided invaluable help with MARK, I give my thanks. I would like to thank Tygerberg Bird Club for their financial support and Brigid Crewe for showing me around the Swartland and giving great crane-related guidance. The National Research Foundation (NRF) provided academic funding, and the EWT provided support. A special word of thanks to Glenn Ramke from the EWT for all the days in the car, your patience and enthusiasm was most appreciated. I would also like to thank Kevin Shaw of CapeNature for the use of his long-term dataset. Thanks to Kevin Drummond-Hay for the use of his photograph for the front cover. I am grateful to Beatrice Conradie for help with formulating my questionnaire. Michael Duckitt, Richard Kruger and Arnold van der Westhuisen were especially helpful with interview setup and advice. To the support staff at the Fitz, especially Hilary Buchanan, I give my thanks. To my CB classmates, who provided endless entertainment and support during tough times, my gratitude is hard to express. Finally, to every farmer who gave me some of their valuable time: your enthusiasm and friendliness was heart-warming.

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Abstract

The Western Cape population of Blue Cranes (*Anthropoides paradiseus*) is of great importance as the largest and most stable population throughout its range. This species is strongly associated with agricultural lands in the Western Cape, and therefore may come into conflict with farmers who perceive them as damaging to crops. Blue Cranes are suspected to be locally nomadic, but little information has been collated to support this and they are also relatively understudied in terms of demographic parameters. This project investigates the viability of the Blue Crane population in three ways: exploring farmer attitudes towards cranes in two regions of the Western Cape (Swartland and Overberg) using 40 semi-structured interviews, generating estimates of survival using Mark-Recapture methods and exploring movement patterns using a long-term data set of resightings of marked individuals. These three components all add important aspects to the overarch ing goal of achieving a better understanding of threats to Blue Cranes in the Western Cape, and thus the population's long-term viability. Perceptions of cranes differed widely between regions: farmers in the Swartland perceived cranes to be particularly damaging to the feed crop sweet lupin (65% of farmers reported some level of damage by cranes), and 40% of these farmers perceived cranes as more problematic than other common bird pests. Farmers in the Overberg did not perceive cranes as highly damaging, although there was concern about cranes eating feed at sheep troughs. Survival was age-structured: individuals in their first year had a survival of 0.6, those in their second and third years that of 0.87 and adult individuals (4+) that of 0.72. The adult survival estimate is suspected to be underestimated due to ring loss. Resightings of colour-ringed cranes suggest that movements in the Western Cape were localized, with an average displacement of 24.6 km from their natal point. Only 3.8% of marked individuals were resighted in both the Overberg and the Swartland regions, indicating that movement between these regions was low and regional fidelity was high. There was significant movement within the Overberg however, and 90% of movements of >10 km were made within this region. This species therefore appears to be resident to locally nomadic in nature. Evidence for natal philopatry was also found: 57% of adults returned at least once to the area where they were ringed as juveniles. These results highlight the need for location-specific management solutions to crop-damage by cranes, and contribute to the understanding of basic demographics for this vulnerable species.

General Introduction

The conversion of natural habitat to agricultural lands, accompanied by the intensification of agricultural practices, is widely acknowledged to be a key cause of biodiversity loss (Tscharntke et al. 2005)**.** Ecologists and conservationists traditionally have focused on untransformed habitat, but this approach has been recognized as insufficient as much of the world's biodiversity is found in agricultural lands (Pimentel et al. 1992). Agricultural lands are therefore key areas for biodiversity conservation, and appropriate agricultural management can enhance biodiversity and ecosystem functioning (Scherr & Mcneely 2008; Perfecto & Vandermeer 2008). Although land conversion and intensification of agriculture can lead to species extinction, farming areas can also provide abundant food resources for animals and benefit even uncommon and endangered species (Tscharntke et al. 2005). Therefore, the promotion of biodiversity on agricultural lands and the incorporation of these areas into large scale conservation planning is a new key research topic.

Any environmental programmes that involve species found in farmlands are mediated through farmers by necessity, and therefore require knowledge of farmers' perceptions. Farms are socio-economic units which are embedded in a larger cultural landscape that can influence how farms are managed (Ahnstrom et al. 2012). Farmer perceptions towards conservation are also influenced by a wide variety of social, cultural and economic factors (Pannell et al. 2006). Social and cultural factors are often in turn influenced by farmer demographics: income, education, age, number of years farming and commercial viability of the mitigation option are all factors that predict willingness to adopt conservation measures (Troy et al. 2005). How these variables affect willingness to adopt conservation strategies and manage wildlife differ widely between studies, often with contradictory results, and decisions made for economic reasons may not always be compatible with conservation actions (Ahnstrom et al. 2012).

Generalisations as to how farmer attitudes relate to management decisions and actions are difficult to make, especially considering that attitudes are not static. Attitudes can change over time, both within an individual and within groups (Eagly & Chaiken 1993). Whether attitudes truly reveal the intentions of an individual is also debatable (Burton 2004). Gaining insight into how farmers perceive an issue or idea is nonetheless vital to inform how urgently conservation techniques are needed or as to why farmers feel they are unable or unwilling to comply with an agri-environmental

scheme. Social factors can be more important in determining human-wildlife conflict than the actual damage incurred (Dickman 2010), although these factors are often ignored in conflict mitigation studies.

Of the 15 crane species (family Gruidae), 11 are classified by the IUCN as threatened: one Critically Endangered, three Endangered and seven Vulnerable species (Harris & Mirande 2013). Cranes face a wide variety of threats, foremost among them being loss of habitat, especially loss of wetlands. Human interference with nests, climate change and collisions with infrastructure are also important challenges (Harris & Mirande 2013). Cranes are also vulnerable to persecution by farmers because of the damage they can inflict on crops as many crane species favour agricultural lands because of the energy-rich plants they provide, especially those close to wetlands and roost sites (Harris & Mirande 2013; Nilsson et al. 2016).

An increasing number of large grazing birds such as cranes, geese and swans has resulted in increasing levels of crop damage to farmers (Nilsson et al. 2016; Salvi 2010). For example, Sandhill Cranes (*Grus canadensis*) were ranked by farmers in Wyoming and Utah as the second most problematic species for crop damage, after Mule Deer (*Odocoileus hemionus*) (McIvor & Conover 1994). Apart from the benefit of food resources, the association with agricultural lands brings significant costs to cranes. Cranes are increasingly exposed to chemicals such as pesticides, and farmer tolerances for damage may be declining as field space becomes limited and costs rise (Harris & Mirande 2013). Farming practices such as burning may also impact nests or wetland habitats, and repeated disturbances may lead to breeding failures or impact on foraging (Luo et al. 2012). The threatened status of many cranes, along with their use of agricultural lands, warrants investigation into how management practices on farms can be altered for mutual benefit to these species as well as landowners.

The Blue Crane (*Anthropoides paradiseus*) is a southern African endemic, with most of the population residing in South Africa, and a small population in Namibia (Allan 2005). It is also South Africa's national bird. Although traditionally associated with grasslands, this species has experienced a significant decline in the grassland biome (Shaw 2003). Conversion of grasslands to forest plantations and croplands and widespread persecution are attributed as the cause (Harris & Mirande 2013). Collisions with powerlines cause significant additional mortality, and can account

for as much as 12% of Blue Crane mortality in the Overberg region of the Western Cape (Shaw et al. 2010). Because of this decline, and the fact that this species is the most geographically restricted of all cranes (Meine & Archibald 1996), it is listed as "Near Threatened" by the *Eskom Red Data Book of South Africa, Lesotho and Swaziland* (Shaw 2015) and "Vulnerable" by the IUCN (Birdlife International, 2013).

Blue Cranes are distributed in three core areas in South Africa: the eastern grasslands, the central Karoo and the Western Cape (McCann et al. 2007). Although not historically found in the Western Cape, this region currently has the largest proportion of South Africa's cranes (48%), followed by the central Karoo (42%), while the eastern grasslands have just 10% of the national population (McCann et al. 2007). Despite declines in many parts of their range, Blue Crane numbers have increased in the Western Cape (Shaw 2003). Previously unsuitable areas of fynbos and Renosterveld have been transformed into agricultural land, which has allowed Blue Cranes to colonise the Overberg and Swartland regions of the Western Cape (Shaw 2003). Cranes are less common in the Swartland compared to the Overberg and are thought to have colonised this area more recently. Co-ordinated Avifaunal Road-counts (CAR counts) suggest the density of Blue Cranes has increased in the Overberg: from 50 birds per 100 km in 1994, to 150 birds per 100 km in 2001 (Shaw 2003). The Swartland has also seen an increase from less than 20 birds per 100km in 1996 to over 60 birds per 100 km in 2001 (Shaw 2003). The Western Cape population of Blue Cranes is the focus of this study due to its importance as a stronghold for this species.

Persecution as a result of crane-caused damage may impact the viability of the Western Cape population of Blue Cranes. However, in order to understand how this factor may impact the population, basic demographic and life history parameters need further research. Currently only one study has estimated the survival rate of cranes using a robust mark-recapture approach (Altwegg & Anderson 2009), based on data collected in the Nama-Karoo. This study uses a similar approach in the Western Cape, building on a long-term dataset of individually marked cranes. Understanding movement patterns is also vital for understanding spatially-explicit processes and is a fundamental, although often poorly understood, population process (Patterson et al. 2008). Very little is known about how Blue Cranes utilise their landscape, and studying this population's movements will allow a better understanding of the threats that they may be exposed to (Higuchi

et al. 2004), as well as impact future research into survival by allowing insight into factors such as site fidelity, emigration and immigration.

My study investigates the Blue Crane population of the Western Cape of South Africa in three ways. Firstly, given their dependence on agricultural land, I assess the tolerance of farmers towards crop damage by cranes, ask how farmers perceive cranes and consider what can be done to foster better relations between cranes and farmers. Understanding farmer attitudes towards cranes was achieved using semi-structured interviews. Secondly, survival rates are estimated for three age classes within this population, incorporating the effects of time and location. Finally, Blue Crane movement patterns within the province are investigated to determine how much cranes move within the Western Cape and how much exchange there is between the Overberg and the Swartland regions of the Cape. Both the survival and movement components draw on a long-term resighting database of individually marked cranes collected by CapeNature from 1997 to 2015. These three components combine to create a more complete picture of the crane population of the Western Cape and allow conservationists to better manage this population.

Chapter 1

Perceptions of Western Cape farmers towards Blue Cranes

Introduction

Although many farmers enjoy having wildlife on their property (Conover 1998) and are motivated to farm in order to feel "close to the earth" (Liffmann et al. 2000), wildlife may also cause a loss of income through direct or indirect damage to crops or farm infrastructure. When a wildlife species is perceived as being highly damaging, farmers' tolerance for that species decreases (Decker & Brown 1982). Most farmers (80%) in the United States suffer wildlife damage on their farm, and 53% of farmers reported that the damage exceeded their tolerance (Conover 1998). Perceived damages are estimated to exceed $2 billion in total annually. In the same study it was found that, of the 80% of farmers that reported wildlife damage, 40% would oppose the creation of a conservation initiative such as a wildlife sanctuary near their property and 26% indicated reduced willingness to provide habitat for wildlife on their farms (Conover 1998). Whether a species is hunted commercially or for sport on a farm influences damage tolerance and farmers' tolerance varies among species depending on the crop being farmed (Conover 1998). Therefore, perceptions of damage can influence both attitudes towards a specific species as well as attitudes towards wider conservation initiatives.

It is often unclear how the amount of perceived damage relates to the actual damage caused by a species (Conover 1994). The conspicuousness of the species in question can influence the perceived level of damage. For example, Sandhill Crane damage was overestimated by farmers because of their large size and because damage was concentrated along the edges of fields (McIvor & Conover 1994). However, whether damage occurs at the level farmers perceive can be irrelevant, because farmers are likely to act on their perception of damage rather than actual damage. Therefore, how farmers manage wildlife damage on their farms depends on a number of factors and is highly species and crop specific.

The structure and method used to implement questionnaire surveys about human-wildlife conflict can have large effects on the results obtained. For example, although open-ended questions are

more time consuming to perform and more difficult to analyse (Kelley et al. 2003), this study uses this structure in order to gain as much insight into the topic as possible. Likert scale questions were not used because this approach performs better when no neutral opinion is included in the scale system, and often suffers from degraded validity when individuals with extreme attitudes are measured (Roberts et al. 1999). As I wanted to capture both neutral and extreme attitudes, a more qualitative approach was chosen. Face-to-face interviews were chosen because personal interviews can generate a higher response rate than other techniques such as telephone or postal surveys (Kelley et al. 2003). Additionally respondents were called before the interview took place because notifying respondents beforehand often can elicit greater cooperation for research (Winter et al. 2007). All these considerations try to account for potential biases and limitations common in research involving human subjects, although each method has trade-offs. For example, although face-to face interviews elicit high response rates they may introduce social desirability or acquiescence biases (Podsakoff et al. 2003).

Social factors are highly influential in human-wildlife conflict situations (Dickman 2010), and so questions such as the age of the farmer were asked because these variables influence to which social group the farmer belongs and their knowledge about farming practices. Age and experience may also influence the willingness of farmers to change farm-management practices (Ahnstrom et al. 2012). Whether the farm has belonged to the family for a long time may also influence farmer attitudes towards their land (Wilson 1996), and so a question about to find out how much influence the respondent had over operations and management practices. Farm size is an important variable because it affects how diversified farmer incomes may be (Weiss & Briglauer 2000; Mishra et al. 2004) and tolerance for wildlife damage may be lower if farmers depend entirely on farm products for their livelihoods. Farm size may also influence how willing farmers are to adopt a conservation measure. For example, Featherstone & Goodwin (1993) found that farmers of larger farms were more likely to invest in conservation measures.

Blue Cranes in the Western Cape favour agricultural fields and pastures, and actively avoid natural vegetation (Allan 1995). They utilise harvested cereal fields during summer, cultivated pastures from July to September, fields with newly emerged crops in early winter and feedlots all winter (Allan 1995). They also nest and breed in agricultural lands, predominantly in harvested cereal fields

and cultivated pastures (Allan 1993). Possibly as a result of this, there have been a number of reports of Blue Cranes being poisoned by land-owners (McCann et al. 2001b; Allan & Ryan 1996). Because of their protected status, harming Blue Cranes is illegal and offenders are liable to fines or jail time. The poisoning may be non-targeted, targeted or incidental (Meine & Archibald 1996). Non-targeted poisoning occurs when cranes are harmed accidently by poison put out for problem species such as geese. Targeted poisoning occurs when Blue Cranes themselves are the target, potentially because of damage caused to crops. Incidental poisoning may occur when chemicals such as pesticides are used on crops and cranes feed on these fields (Allan 1995; Meine & Archibald 1996). Cranes' dependence on agricultural lands means that the potential for conflict with farmers is high, and the Western Cape's importance as a stronghold for the species makes research into farmer attitudes vital. This chapter investigates farmer tolerance towards Blue Cranes, estimates the timing and extent of damage to crops (if any) and whether farmers perceive cranes to be a problem species. The findings will allow conservation managers and farmers to create strategies that both minimize the damage and allow the continued growth of this important population.

Methods

Study area

Blue Cranes are mainly found in the lowland areas of the Western Cape, which have been largely transformed for agriculture. The percentage of land in this province under agriculture is estimated to be 89.3%, of which 78.7% is grazing and 21.3% is potentially arable land (Western Cape Government: Dept. of Agriculture 2014). The two regions of the Western Cape that support the most Blue Cranes are the Overberg and the Swartland (Shaw 2003; Figure 1). The main agricultural products in the Overberg are fruit, field crops (primarily wheat and canola) and livestock pasture (Conradie et al. 2009). The main agricultural products of the Swartland are field crops (primarily wheat and oats), intensive animal farming (such as dairy or chickens) and other livestock (Conradie et al. 2009). The climate in both areas is Mediterranean with rainfall mainly in winter. The Swartland tends to receive less rainfall than the Overberg, with a mean annual rainfall ranging from 300 mm in Hopefield to 490 mm in Malmesbury, compared to 600 mm in Theewaterskoof in the Western Overberg and 450 mm in the eastern portion on the Agulhas Plain (climate-data.org, n.d.).

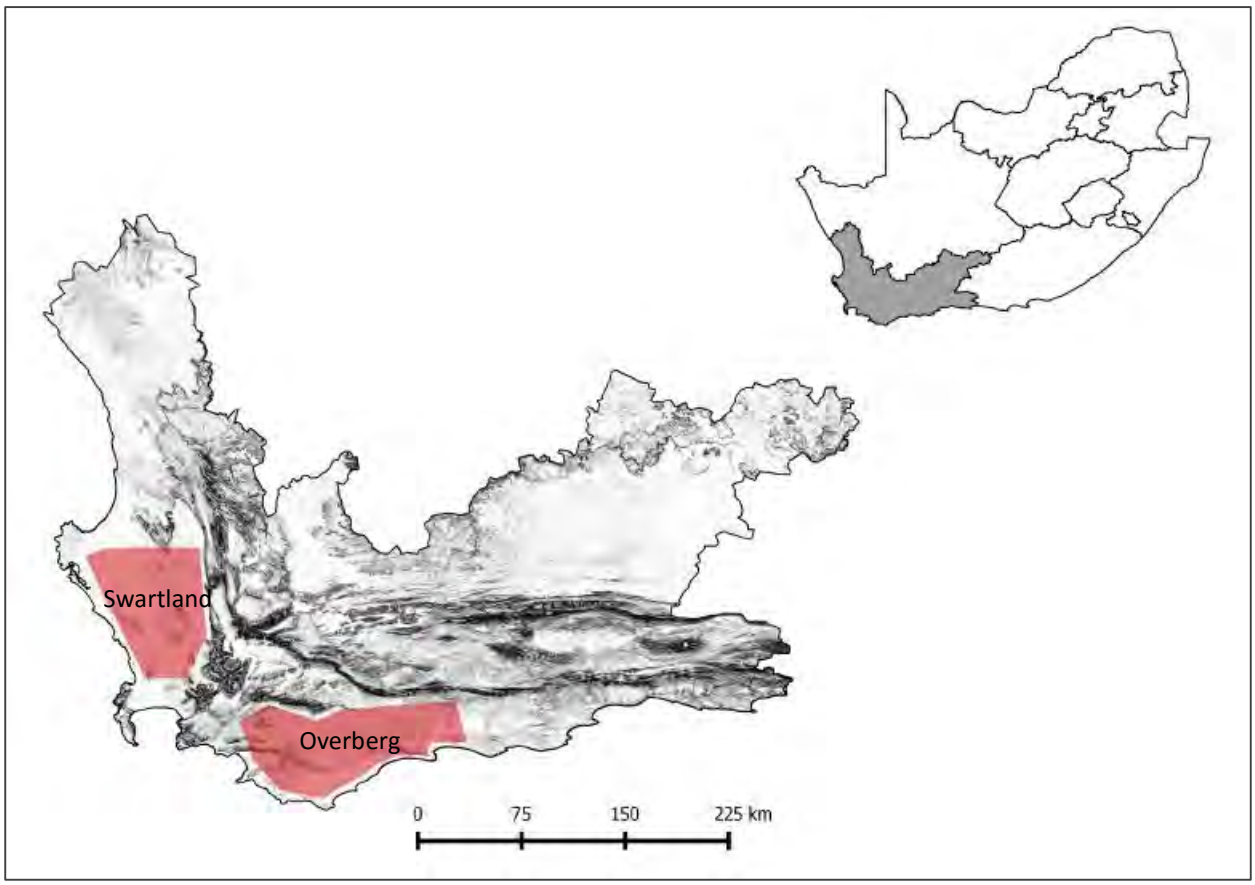

Figure 1: The Western Cape Province (black indicating high elevation), showing the two study areas, the Swartland and the Overberg (inset: the Western Cape Province in relation to the rest of South Africa).

Interviews

Questionnaire design

The interviews were designed to infer the attitudes of farmers towards Blue Cranes and the factors underpinning these attitudes. Of particular interest was whether cranes were perceived as damaging to crops or other farm assets, and if so, how severe the damage was perceived to be, when the damage occurred and what crop type or land use was affected. Other questions revolved around damage mitigation methods: what methods (if any) the farmer had attempted and how successful they were, as well as how amenable the farmer would be to test various other methods. An attempt was made to find out if there were any methods or techniques used to manage cranes that the farmers found unacceptable. The interviews also included a biographical profile of the farmer and details about the farm (see “Biographical profiles” section below).

The questionnaire was mainly comprised of open-ended questions because possible replies were largely unknown and varied. The interviews were semi-structured by including a standardized set of questions, which were asked in the same order (see Appendix for questionnaire). The interviews included a cover letter with information about the research, with name and contact details of the researcher. This provided informed consent as well as encouraged participation. It was stressed that the interview was completely anonymous. The interview questions were pre-tested on two conservation professionals familiar with Blue Cranes and on one pro-conservation farmer. Questions were then edited for increased clarity. Ethical clearance was obtained from the University of Cape Town's Faculty of Science Research Ethics Committee (Ethics number: FSREC 38-2015).

Biographical profiles and farm characteristics

The questions in this section were used to obtain a profile of the respondent and of their farm. Questions included the age of the farmer, years of farming experience, the respondent's position on the farm, whether the farm had belonged to or been farmed by previous generations and size of the farm (in ha). A breakdown of the hectares of each crop type or land use on the respondent's farm was requested in order to assess differences between farms with and without Blue Crane-caused damage, and to assess how much income was lost as a result of that damage. A question was also included to assess perceptions of climate change because of concerns that a drying trend in the Western Cape may influence crop choice in these regions (Erasmus et al. 2000) and thus influence crane populations.

Attitude and perceptions of damage

Attitude was explored by a number of open-ended questions and one closed-ended question. The close-ended question asked the respondent to rank Blue Cranes, Egyptian Geese (*Alopochen aegyptiacus*) and Spur-winged Geese (*Plectropterus gambensis*) from one to three in terms of the problem they posed. The open-ended questions focused on perceptions of damage, and included asking for an estimate of the amount of damage Blue Cranes did to crops or losses of other farm items such as feed. Answers could be given either in monetary terms or in percentage of crop lost. Respondents were asked which months cranes and/or geese caused the most damage (if any). In

terms of attitudes towards cranes, respondents were asked if cranes were perceived as damaging in any way and if their attitude towards cranes has changed (positive or negative) for any reason.

Management questions

These questions attempted to find out what techniques respondents used to manage cranes and geese on their farms, what methods they were comfortable using on cranes, and if they were aware of any methods used to manage cranes with which they were uncomfortable. I asked the respondents what they thought of various proposed management techniques including using scarecrows, gas-cannons, trough alterations and shooting to scare birds away, as well as no management. Farmers were also asked what the average size of flocks seen on farms was. Flocks were defined to the farmers as 20 birds or more grouped together at one time. If a farmer had not seen a flock of 20 or more the farmer was given a *not applicable* for that question.

Other questions

Other questions were based on using the farmers' observational skills to add to the current knowledge about cranes. Respondents were asked what they thought may be harmful to cranes in the region in order to try to understand what other threats this population may be facing. I asked respondents if they had seen any crane roosts or breeding pairs on their farms and how much the large flocks moved around during the day.

Attitudinal score

Respondents were given a score upon completion of their interview based on five variables to evaluate how problematic the respondents viewed cranes to be. A value was given for each variable and then the values were summed: the higher the score, the more problematic the cranes were to the respondent. The variables used were: a) reported damage by cranes (1 or 0), b) reported damage as other than minimal (1 or 0), c) gave cranes a problem rank of higher than 3 (1 or 0), d) reported using some technique to manage cranes on their farms (1 or 0) and e) reported need for management techniques for crane damage (0 if no need for any management technique suggestions, 0.5 if had some need for techniques, 1 if had a need for management techniques). This

summed to a possible score of five, which indicated that that respondent viewed the cranes as particularly problematic.

Respondent selection

The interview respondents were selected via a "walk" through the community known as the "snowball" approach (Kelley et al. 2003; Browne 2005). I established contact within an area through one or two farmers known to be knowledgeable about the region or Blue Cranes. These first contacts were generally involved in Farmer Associations of an area. They were asked to provide details of farmers within the community who either had large crane flocks on their farms or were knowledgeable in some way about Blue Cranes. Upon completion of the interviews, some of the respondents then in turn provided details of other farmers of interest and so on. The snowball approach is not random, but rather targets specific individuals within a population. This was necessary however as not all farmers in the region had ever experienced Blue Cranes on their farms (e.g. Blue Cranes would never visit a viticulture farm, based on the behaviour of this species).

An initial phone call was made to each respondent to arrange for the interview and to provide a brief background to the study. Interviews were then conducted in person at the respondent's home. Interviews lasted roughly 30 minutes, and were conducted in the respondent's language of choice (English or Afrikaans). I conducted 90% of the interviews, either alone or with Endangered Wildlife Trust (EWT) extension officer, Glenn Ramke. The EWT extension officer conducted four interviews alone. These interviews were pooled with the interviews conducted by the author, as there were no obvious differences in response rate or quality of response.

I conducted forty semi-structured interviews during September and October of 2015 with farmers in the study areas: 20 in the Swartland and 20 in the Overberg. A sample size of 20 interviews per region was decided upon during data collection, based on the level of variation in respondent answers in a region. Although Swartland farmers gave more varied responses, no novel points were raised after 15 interviews. Difficulty in finding more farmers available in the limited time also contributed to the decision to stop at 20 interviews per region. A minimum response rate, calculated as the number of completed interviews / (complete interviews) + (refusals + non-

contact) (AAPOR 2010), of 67% was obtained for the Swartland and 71% for the Overberg (Table 1). Only one farmer refused to participate, the reason given as “not interested in birds”.

Table 1: Summary of responses to requests for interviews with farmers conducted in the Swartland and Overberg regions of the Western Cape.

Region	Number attempted to contact	No answer	Away/busy	Refused to participate	Number conducted
Swartland	30	6	4	0	20
Overberg	28	5	2	1	20
Total	58	11	6	1	40

Data Analysis

Differences in means of biographical variables between areas were computed using t-tests or Mann-Whitney U tests (depending on the distribution of the data) and chi-squared goodness of fit tests were used for count data. Generalised linear models (GLM’s) were used to examine the effect of both biographical and crop variables on damage (0/1) and attitudinal score. Damage followed a binomial distribution, while score was quasi-Poisson distributed. Crop variables were the number of hectares of each crop reported by farmers, while demographic/farm variables included age, farm size, experience, contact with conservation agencies, location of farm (Swartland or Overberg) and size of Blue Crane flock seen on farm. All statistical tests were computed using R (R Core Team 2015).

Multiple Correspondence Analyses (MCA) were conducted for two sets of data. No standardization of units was necessary as this method regards all variables as nominal and does not weight values in any way. The first set involved variables about the perception of damage caused by Blue Cranes and included three variables, namely the presence or absence of damage (0 or 1), level of damage (1: minimal, 2: medium, 3: high) and problem rank (1, 2 or 3 where 1 indicates Blue Cranes viewed as most problematic species out of three options) . The second set involved attitudinal and management variables, including need for management options (0: no need, 0.5: some need, 1:

strong need), management currently used for Blue Cranes (none, gas-cannons, scarecrow, trough alterations, shoot to scare away) and perception of problem severity (insignificant problem, medium problem and significant problem). For each analysis the eigenvalues were examined and a scree plot used to find the number of dimensions that explained most of the variation in the data. Each set was then plotted in multivariate space by respondent, and grouped by area (Swartland and Overberg). This analysis was performed using the "FactomineR" and "Factoextra" packages in R.

Results

Biographical profiles and farm characteristics

All 40 respondents interviewed were white males and most (95%) were Afrikaans speaking. The average age of respondents was 40.9 ±12.1 (SD) years (range 21-68), with respondents from the Swartland (36.2±12.2 years) significantly younger than those from the Overberg (46.1±9.9 years; t=2.77, p=0.008). The average number of years' respondents had been farming (experience) was 15.6 ±11.6 years, and tended to be greater for Overberg farmers (W=257.5, p=0.059). Average farm size was 1559 ±1105 ha (range 382-5802 ha), and did not differ significantly between regions (1603±1359 for Swartland farms and 1512±808 for Overberg farms; W = 221.5, p-value = 0.569). Most respondents (34/40) had farms that had been in the family for more than one generation. Only 14 of the 40 respondents (7 from each region) had had some contact with a conservation initiative or agency on their farms. Participation in conservation activities ranged from getting advice regarding management of livestock predators to the creation of plant reserves on their land. Generally, there was strong overlap in demographic variables between the Swartland and Overberg regions.

The three main crops or land-uses reported in the Swartland were wheat, sheep pasture and beef pasture, whereas in the Overberg it was lucerne, barley and wheat production (Table 2). There was more sweet lupin (W=46.5, p<0.01) and beef pasture (W=137.5, p<0.05) in the Swartland region, but more barley (W=355.5, p<0.01), canola (W=271, p<0.05) and lucerne (W=360, p<0.01) in the Overberg. The average number of hectares of medic pasture, wheat and vegetables was similar in the two regions. Bitter lupin was close to significantly more abundant in the Swartland (p=0.06).

Table 2: Average hectares of crop/land-uses reported by respondents in the Overberg (n=20) and Swartland (n=20) regions of the Western Cape (compared with Mann-Whitney U-tests between regions; NS = not significant).

Category	Crop/land-use	Overberg	Swartland	Significance
Cover crops	Medic pasture *	134.8±189.6	132.8±171.9	NS
	Bitter lupin **	12.4±22.1	42.3±57.1	NS
Cereals	Wheat	273.7±150.4	427.8±342.2	NS
	Barley	246.1±161.4	7.5±24.5	p<0.01
	Oats	65.2±84.5	118.6±170.1	NS
	Treticale	0.0±0.0	20.0±52.3	NS
Oil seeds	Canola	147.2±116.7	84.7±159.6	p<0.05
Pasture	Sheep pasture	144.7±202.3	203.8±299.0	NS
	Beef pasture	20.8±76.3	178.8±261.3	p<0.05
Forage crops	Lucerne	287.4±288.4	0.0±0.0	p<0.01
	Sweet lupin**	3.2±11.6	95.8±101.9	p<0.01
Other	Vegetables	9.5±28.6	8.5±24.6	NS
	Vineyards	52.6±229.4	5.0±20.1	NS
	Plant reserve	10.6±26.8	3.5±15.7	NS

**Medicago* spp. ***Lupinus angustifolius* varietals

Perceptions of climate change

The perceptions of recent (within the last 10 years) climate change varied widely between the Overberg and the Swartland. The most common response (7/20) in the Swartland was that there was currently a drought, but other than that no change was apparent. Five respondents commented that winter was starting later in the year, and four farmers suggested that the seasons (especially winter) were getting shorter. Three farmers in this region commented that there was less rain in winter than previously. In the Overberg the most prevalent response (8/20) was that rain events were more intense and abnormal (rain at unexpected times, intense storms). The next most common response was that there was no observable change in climate (7/20). Four farmers perceived that the cool seasons were getting shorter, and one that the climate was warming.

Most farmers in both the Swartland (65%) and the Overberg (60%) reported that they have not changed the type of crop they farmed in recent years. Fifteen out of forty farmers changed their

crops, the most common reason cited was that the financial viability of the crop had either decreased or increased (6/15). In the Swartland too little rain was cited twice as the reason for the change from crops to more livestock farming, and damage to lupin crops also twice. Other changes in the Swartland included farming more medics, lupins and peas (each reported once). Planting more canola was reported three times in the Overberg, and farming less canola, lucerne, cattle, lupin and arable land reported once. The amount of canola planted was increasing, as farmers had recently begun planting it directly after a pasture ley as this made it easier to manage weeds.

Perceptions of damage

More than half (55%) of the farmers reported some damage to their crops or a loss of sheep feed by Blue Cranes; 65% of Swartland respondents and 45% of Overberg respondents (χ^2=0.73, NS). However, significantly more Swartland farmers estimated the damage level as high (30%) than Overberg (0%) farmers (p= 0.020, Fisher's exact test). Nine Swartland farmers reported low damage, compared to 17 Overberg farmers (χ^2=2.46, NS). These trends are also found in the problem rank that respondents were asked to give Blue Cranes; 40% of Swartland respondents ranked Blue Cranes as more problematic than Egyptian or Spur-winged Geese, 35% ranked them as the second most problematic species, and only 25% ranked them as the least problematic of the three. All Overberg farmers ranked Blue Cranes as the least problematic species.

The presence or absence of damage was associated with the size of the flock seen on farms (Type II Anova, χ2=11.19, p<0.001) and with problem rank (χ2=9.702, p=0.002) but not with age of farmer, their experience, farm size, contact with conservation agencies or region. Damage was reported if flocks were large, and if Blue Cranes were ranked as more problematic than geese species. The average (±SD) flock sizes reported was 94.4 ± 87.9 birds in a flock in the Swartland, and 48.3 ± 38.8 birds in the Overberg , which did not differ significantly (W=148, p=0.154). Two farmers from each region reported that they had never seen a "flock" on their farms i.e. 20 birds together at one time. The crops or land-uses associated with the damage variable (generally with its absence) were barley (χ^2 =5.43, p=0.019), vegetables (χ^2 =6.90, p=0.009), plant reserves (χ^2 = 5.53, p<0.001) and lucerne (χ^2 =7.81, p=0.005). However, these crops are either farmed in very small amounts (such as

vegetables and plant reserves) or are concentrated in one area (lucerne and barley are mainly farmed in the Overberg).

There was little variation in the responses of Overberg farmers, and they were associated with the absence of damage, the least severe damage severity and the lowest problem rank (Figure 2). Swartland farmers had much more variable perceptions of crane damage. The responses of Swartland farmers were associated with all options for level of damage and problem rank. Absence of damage, low damage levels and low ranking of cranes were associated (Figure 2), which indicates that there is consistency across answers to questions regarding damage. Similarly, the presence of damage was associated with the highest problem rank. See appendix Figure 1 for placement of individual respondents.

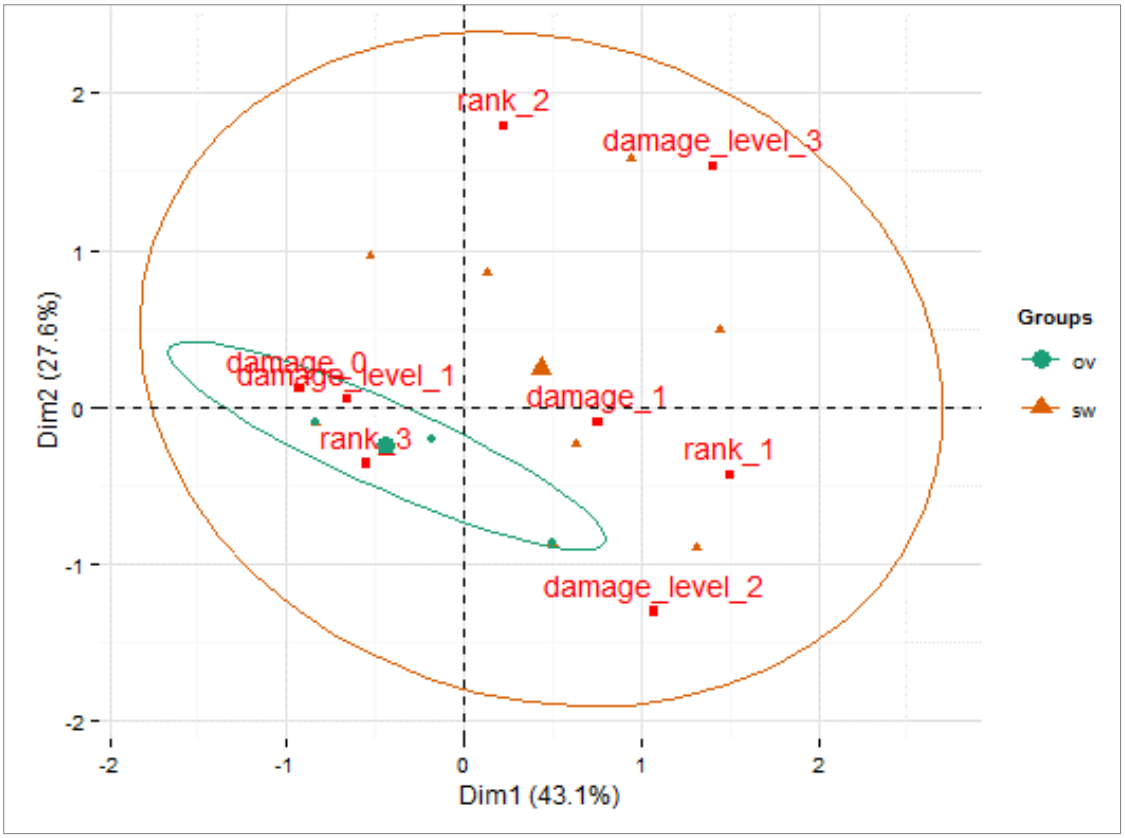

Figure 2: Multiple Correspondence Analysis for damage perception factors including damage (0: absent or 1: present), level of damage (1: minimal, 2: medium, 3: high) and problem rank (1, 2 or 3 where 1 indicates Blue Cranes viewed as most problematic species out of three options) for respondents in the Overberg and Swartland. Smaller symbols indicate individual respondents by region, while the larger symbol indicates the centroid point for those respondents. Ellipses represent the area where points are concentrated for each respondent region. The first two dimensions explained 70.7% of the variance in the data (Eigen values: Dim. 1: 0.72, Dim. 2: 0.46).

The crops reportedly damaged by cranes in the Swartland included sweet lupin, canola, wheat, and medics, but all Swartland farmers emphasised sweet lupin as the cranes' crop of choice. Damage occurred mainly when the crops were young and forming buds or shoots, which takes place during winter for most of the crops grown in this region. All Swartland farmers identified winter (June-September) as the time of peak crop damage by both cranes and geese. Damage estimates averaged 15% of the lupin crop (range 1-100%), but confidence in these estimates was low: most respondents were unsure which bird species was responsible for crop damage as geese were often

seen in lupin fields with cranes. Regardless of the species responsible, damage was severe enough for two of the farmers interviewed to stop farming sweet lupin completely.

In the Overberg the only damage reported was loss of sheep feed at feeding troughs. Four farmers reported that feed loss to cranes increased in the dry months from January to June, while five farmers reported that losses mainly occurred between June and August. No farmer was prepared to estimate the amount of feed lost to cranes with any degree of confidence. A few farmers (n=3) were concerned that cranes may prevent young lambs from accessing the feed troughs and thus cause a loss of condition.

Attitudes and management

The overall attitude of respondents toward cranes ranged widely both within and between areas, with Swartland farmers regarding cranes as more problematic (score of 2.73±1.91) than Overberg farmers (score of 1.28± 1.54; t=2.64, p=0.012). The larger the estimated size of flocks seen on farms the higher (and thus more problematic) the score (Type II Anova, χ^2 =9.48, p=0.002; Figure 3). Score was nearly significantly associated with age of the farmer (Type II Anova, χ^2 =2.99, p=0.083), where older farmers had slightly lower (and thus less problematic) scores than younger farmers. Score was not significantly associated with any other demographic variable or crop variable.

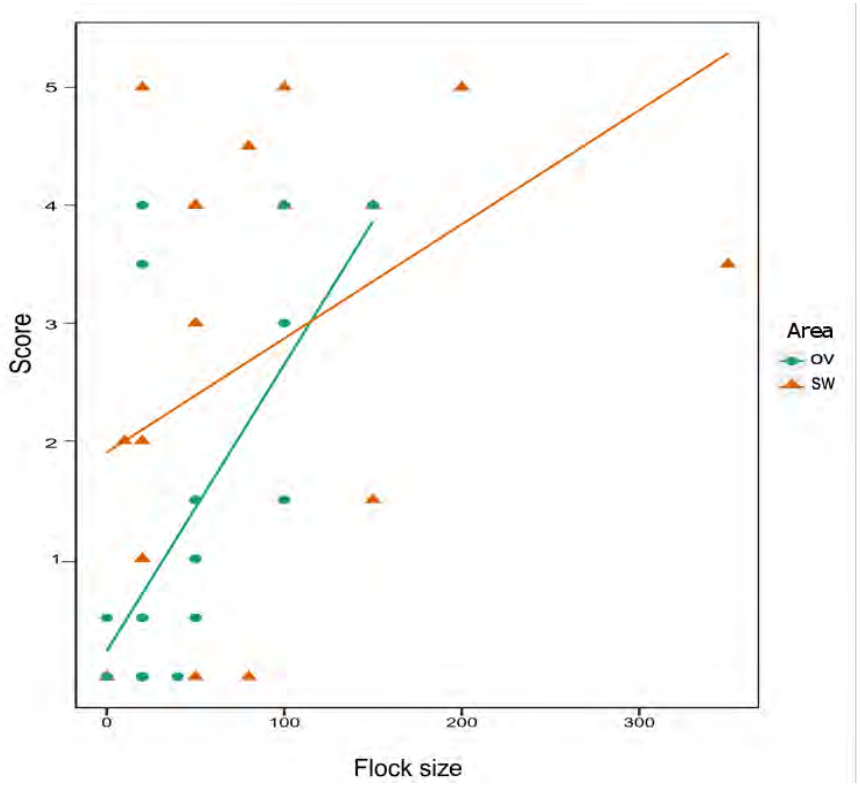

Figure 3: Attitudinal score of respondents from the Overberg and Swartland in relation to the estimated size of the flocks of Blue Cranes seen on their farms. Regression lines are fitted for each region.

The MCA analysis of attitudinal and management variables indicated that the Overberg respondents were strongly clustered around the "no current management" (none), "no need" (0) or "some need" (0.5) for management options and "insignificant" problem severity (Figure 4). The Swartland respondents were widely scattered, and were associated with attitudes and management techniques across the spectrum. Significant problem severity was associated with the management practice of shooting to scare away cranes, which was the most extreme management technique mentioned as regularly used. Medium problem severity was associated with the management techniques of trough alterations, gas cannons and scarecrows. Insignificant problem severity was related to no current management used. See appendix Figure 2 for placement of individual respondents.

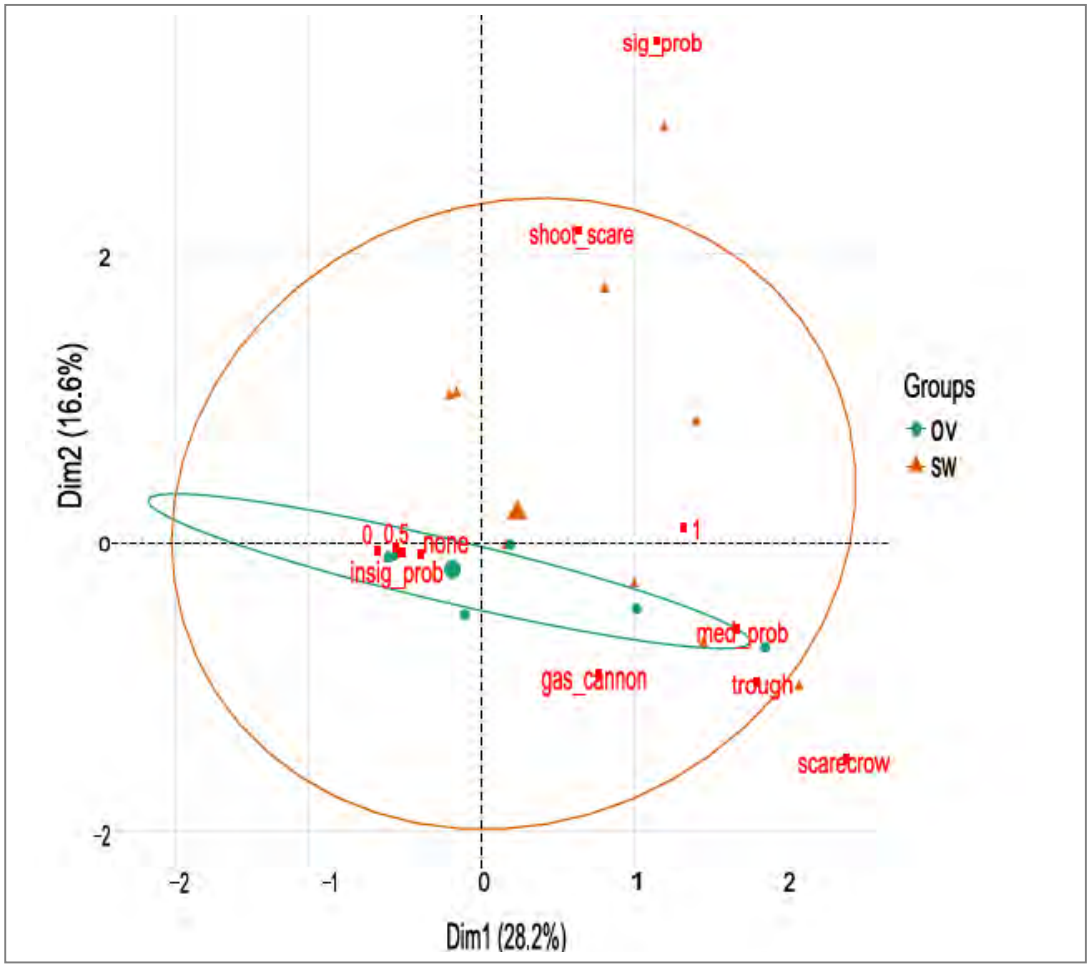

Figure 4: Multiple Correspondence Analysis for attitudinal and management factors including need for management options (0: no need, 0.5: some need, 1: strong need), management currently used (none, shoot to scare away, scarecrow, trough alterations) and perception of problem severity (insignificant problem, medium problem and significant problem) for respondents in the Overberg and Swartland. Smaller symbols indicate individual respondents by region, while the larger symbol indicates the centroid point for those respondents. Ellipses represent the area where points are concentrated for each respondent region. The first three dimensions explained 60% of the data (Eigenvalues Dim. 1: 0.75, Dim. 2: 0.44, Dim. 3:0.39).

In the Swartland, 45% of respondents indicated a strong need for alternative management strategies, while 20% of the respondents in the Overberg reported this (χ^2=1.92, NS). Nine respondents in the Swartland indicated that they would be interested in a new technique if it was

cost-effective, not labour intensive and also helped reduce the damage caused by geese. The other 11 Swartland respondents indicated that they would be unwilling to spend much time or money on crane management. The perceived severity of damage (level 1, 2 or 3) was significantly different between these two groups (p=0.027, Freeman-Halton extension of Fisher's exact test), with those that perceived a high level of damage being more interested in management alternatives. Five respondents from the Swartland reported that they did not currently manage Blue Cranes on their fields because they quickly became habituated to all available techniques such as gas-cannons and shooting to scare them away. Most farmers (75%) in the Overberg reported that they did not manage cranes on their fields because they did not view them as a problem. Two farmers reported that cranes at troughs were not a problem for them because they did not feed their sheep in permanent troughs, but rather moved feeding spots every day. Three Overberg farmers modified their permanent troughs to try to exclude cranes from feeding by putting a roof over the trough or a line of wire around the trough; two farmers reported that these modifications were successful.

Perceived threats to cranes

Respondents in the Overberg were more aware of potential threats to cranes (90% reported at least one threat) than farmers in the Swartland (only 40% reported at least one threat). The major threats listed were collisions with powerlines, and both adult and immature cranes getting caught in fences (Table 3). Poisoning, either targeted or non-targeted, was not perceived as a major threat in either region. One farmer in the Swartland reported having seen deliberate poisoning of 15-20 cranes on another farm. Other concerns were chemical ingestion from eating crops sprayed with pesticides, death as a result of the ingestion of urea from feed troughs, destruction of nests by harvesting machinery, leg deformities and hunting by farm workers. All respondents in both regions were aware of the protected status of cranes however, and the illegality of persecuting this species. This was brought up by every farmer without specifically being asked about it.

Table 3: Number of respondents from each study region that reported a type of threat to Blue Cranes.

Threat type	Swartland	Overberg	Total
Powerline collisions	3	12	**15**
Caught in fences	2	11	**13**
Poisoning: deliberate	1	0	**1**
Poisoning: accidental	0	2	**2**
Chemicals for crops	0	2	**2**
Leg deformities	1	0	**1**
Urea in troughs	0	1	**1**
Hunting for meat	0	1	**1**
Harvesting machinery	1	0	**1**
None	12	2	**14**

Discussion

The results of the interviews indicated a location-specific pattern of crop/asset damage by Blue Cranes in the agricultural lands of the Western Cape. The number of farmers reporting some level of damage was not significantly different between regions, but the severity of the damage was perceived to be greater in the Swartland than in the Overberg. Blue Cranes in the Swartland were reported as especially damaging to one specific crop: sweet lupin. Damage occurred at the initial growth stage of the plant, generally from June to September. Although some farmers reported losing their whole lupin crop, many farmers were unsure as to the level of damage and how much this translated into monetary losses. Others commented that they were unsure which species caused the majority of the damage, although 40% of Swartland farmers ranked Blue Cranes as more problematic than Spur-winged and Egyptian geese, despite the much greater abundance of geese in this region (Mangnall & Crowe 2003) . It may be that the conspicuousness of Blue Cranes influences farmer's perception that Blue Cranes caused more damage than other species (Naughton-treves & Treves 2005). This phenomenon has been observed in overestimates of crop damage caused by Sandhill Cranes (McIvor & Conover 1994) and underestimations of damage caused by geese on rye fields in the USA (Conover 1988).

Another reason for the differences in perceptions of damage in the two regions may be that it is easier to see the damage caused to lupin fields than to estimate how much feed is consumed by cranes at feed troughs. For example, Sandhill cranes routinely graze at the edges of fields, and thus farmers overestimate the damage they cause as it more visible than damage caused in the centre of the field or to the roots of plants (McIvor & Conover 1994). The presence of damage and attitudinal score of farmers was related to the size of flocks on farms. This is likely to be similarly related to the conspicuousness of large flock on fields, as well as the simple relationship of more cranes means more crop or feed is eaten. The larger estimated flock size in the Swartland may be as a result of Blue Cranes congregating on specific fields, probably small fields of sweet lupin, while in the Overberg their feed source (sheep troughs) were scattered over many different fields.

Perceptions of damage may also be influenced by time of exposure to the damage. Blue Cranes arrived more recently in the Swartland than the Overberg (Shaw 2003) but also their numbers may have only recently grown to such a point that they are perceived as a pest, and thus the farmers here may be more aware of any damage they may cause. People who have had experience living alongside a wild species tend to be less afraid of them (Røskaft et al. 2003), and Knuth et al. (1992) found that people who had experienced damage to fields by deer over a long period were less concerned about the damage than people experiencing deer damage for the first time. The result that older farmers were less antagonistic towards cranes (based on their attitudinal score) than younger farmers may be evidence of this, although this variable was not quite significant and years of experience was not significantly related to score.

No biographical variables were linked statistically to the presence of damage or to the attitudinal score given to respondents. Studies relating biographical variables to environmental or conservation issues are commonly contradictory (Ahnström et al. 2012) in terms of both the sign of the relationship and its statistical significance. Although Overberg farmers were older and more experienced than Swartland farmers, all respondents belonged to one cultural group: white Afrikaans male farmers. Cultural and social identity plays an important role in determining attitudes towards environmental issues (Marchini & Macdonald 2012), because an individual is encouraged

to emphasise similarities between himself and the group. Behaviours such as persecution of problem species have been linked to a group's social/cultural identity and its norms (Marchini & Macdonald 2012). Because all respondents in our study belong to the same cultural group, identifying a relationship between negative attitudes and biographical data may be difficult, because a prevailing norm may influence attitudes regardless of these variables.

Predicting what crops may be associated with the presence or absence of damage was difficult. The hectares of a crop farmed could not be related to damage, mainly because it is not the amount of a crop that determines whether a crane will feed on it but rather the identity of the crop itself. The mere presence of lupins was also not a predictor of damage, probably because some fields and areas are intrinsically more attractive to cranes than others. This has been found in relation to damage by the Common Crane (*Grus grus*), where stubble fields, fields close to roosting sites and fields that have been recently harvested had a higher probability of crane presence (Nilsson et al. 2016; Végvári et al. 2002). Similarly Goroshko (2010) found that Demoiselle Cranes (*Anthropoides virgo*) and Hooded Cranes (*Grus monacha*) visited fields that were 15-20km away from roost sites 15-30 times less often than those planted closer to roosts. Therefore predicting whether damage will occur on a specific farm will likely require data on roost locations for large flocks and frequency of large flocks in the area.

Climate change and associated changes in crops has the potential to affect Blue Crane populations in the Western Cape. This province is expected to get drier under climate change, and face major water supply issues (De Wit & Stankiewicz 2006), which is predicted to have strong impacts on the agricultural sector. Erasmus et al. (2000) predict that lower precipitation will cause a decline in water-intensive farming products such as vegetables, fruit and dairy farming and a concomitant increase in wheat, barley, beef cattle and sheep. Overall, this will possibly benefit Blue Cranes as they derive little benefit from the water-intensive crops listed above, but utilise harvested wheat fields for breeding and food, and the increase in beef cattle and sheep will result in increased planted pastures such as sweet lupin. Damage to crops by cranes therefore has the potential to increase in the future. An increase in viticulture is currently occurring in the Swartland, which may become a problem as this land-use does not support Blue Cranes (Hofmeyr 2012). While most of

the farmers in this study did not report any change in crops recently, this is probably biased by the fact that few of the farmers interviewed farmed water-intensive crops (two farmers in the Swartland had dairies but combined this with extensive pastures). Although it appears climate change may benefit cranes in terms of crops farmed, less precipitation is likely to have a negative overall effect on the farming economy (Erasmus et al. 2000) which may make farmers less tolerant of any damage to crops. This may have already been apparent during this study: the Swartland experienced a severe drought during 2015, while the Overberg had a normal amount of rain.

Farmers in the Overberg were considerably more aware of threats to Blue Cranes than farmers in the Swartland. This is probably due to more exposure to both Blue Cranes and to the conservation initiatives that have been conducted in this area for over 20 years. There is no reason to suspect that there are more threats in the Overberg than in the Swartland: powerlines and wire fences are ubiquitous in both regions, but were scarcely mentioned by Swartland farmers. The density of cranes in the Overberg is higher however (Shaw 2003), which may mean more farmers here have had personal experiences with mortalities on their farms. Although there was no difference between the two regions in the number of farmers who had had direct contact with conservation initiatives, the mere presence of these groups may raise the awareness of farmers towards crane threats. Discussion with friends and neighbours who have had contact with agencies could foster awareness of the conservation issues surrounding this species. Farmer's awareness of environmental threats has been found to have a consistent impact on whether they adopt a conservation initiative. For example, farmer awareness of soil erosion is positively correlated to the adoption of soil conservation practices (Knowler & Bradshaw 2007). Utilisation of social networks and access to information can also significantly improve adoption of conservation practices (Lemke et al. 2010; Knowler & Bradshaw 2007). It is therefore hypothesised that the consistent exposure of the Overberg farmers to these conservation initiatives, even indirectly, has resulted in an awareness of crane threats.

Farmers in the Swartland show more need for alternative management options than farmers in the Overberg. Attitudes to management are variable though. Some farmers (those with more severe damage) cited a strong need for solutions, while those with less severe damage reported that

damage was not bad enough for time or money to be spent. This indicates that farmer responses to damage are proportional to the amount of damage incurred, which suggests no inherent bias against cranes. This is encouraging as a disproportionate response to damage is often found in human-wildlife conflicts (Dickman 2010). This was evident in the Overberg as well: some farmers had tried to alter the designs of their troughs to exclude/discourage cranes, while others did not feel the need to do so. Farmers without permanent troughs, or those that moved their sheep feeding stations each day were unconcerned about cranes. The most common criteria for an alternative management option were cost effectiveness, time and labour to perform the management and the ability to also reduce geese-caused damage.

Management recommendations to lessen crop damage, and therefore the potential for conflict, are complex. Recommending to farmers in the Swartland that they plant less sweet lupin is the simplest answer, but probably not practical. Sweet lupin is used by these farmers as fodder for livestock and forms a vital (if small) component of their crop. The Swartland is an area with limited natural fodder: the majority of the untransformed landscape consists of unpalatable *fynbos* and Renosterveld species. Several approaches have been attempted in Europe and North America to deal with crop damage caused by crane species. For example, compensation schemes have been implemented in France (Salvi 2010) and in Hungary farmers have been subsidised to create "crane-friendly" fields, where a certain proportion of the crop remained unharvested and non-harmful pesticides are used (Végvári et al. 2010).

Another common mitigation method involves the creation of artificial food sources in order to lessen damage by cranes. These include "lure fields", "lure bands" or artificial feeding stations, and have been successful in some cases (Shanni et al. 2010; Goroshko 2010; Salvi 2010). "Lure fields" involve planting a small field of an attractive crop near roosting sites of cranes. Millet is a favourite food for Demoiselle and Hooded Cranes as well as waterfowl such as geese, and if self-seeding and unharvested, can sustain itself without planting for many years (Goroshko 2010). Visual and audible disturbance techniques such as gas cannons and predator decoys are used to disperse cranes from problematic fields (Austin 2010). Lure fields may work to keep cranes off lupin fields and should be

researched further. The income saved from less damage by cranes should make these fields economically viable for farmers.

A promising solution developed in North America for damage caused by Sandhill Cranes involves the application of a distasteful substance to seeds. This substance, named “Avipel” (www.avipelshield.com) is non-toxic, compatible with farming methods and machinery and persists in the plant when they form shoots (Barzen et al. 2010). This substance seems to be effective at deterring crane herbivory, and is better than disturbance methods such as gas cannons, as cranes do not move to a nearby field but eat alternative foods such as insects (Barzen et al. 2010), limiting damage to neighbours. Avipel is not currently available in South Africa although the company Eco-Guard has recently started the process of registering this product in South Africa. Avipel is also only available in corn and rice variations. Additionally it is not known whether the product will be effective at the stage when the plant is forming buds, which is when most of the damage to sweet lupin occurs. It may however be possible to repel cranes from eating sheep feed at troughs in the Overberg, provided the feed is corn based. There are various bird-repellent chemicals registered for use in South Africa (e.g. Methiocarb) but these can kill fish and insects (Reidinger & Miller 2013). Therefore I recommend further research into Avipel’s effectiveness on repelling Blue Cranes on various crops or at feed troughs.

The nature of research involving human subjects implicitly involves biases, although ever effort was made in this study to reduce these. However, although there is no reason to suspect that the presence of the extension officer changed the interview process, as interviews conducted without the officer yielded the same level and quality of responses as those with the officer, there may have been an undetected bias here. Also although it was made clear that I hoped to contact people with as many differing viewpoints as possible when I approached the farmer associations for contact details, they may have unconsciously provided details of either negatively or positively biased farmers. Despite these weaknesses, there is evidence of consistency between answers of questions that are theoretically linked, which indicates that the questionnaire performed as expected. For example absence of damage, low damage levels and low problem ranking of cranes were associated with each other in the MCA anaylsis.

Numerous conclusions can be made from this research into farmer perceptions of Blue Crane-caused damage in the Western Cape. Primarily, there is a need for location-specific solutions. The Swartland may require the use of distasteful chemicals, lure fields or artificial feeding sources to keep cranes off crops, especially sweet lupins. Generally there was a strong need for alternative management strategies in this region. Many farmers here indicated their dissatisfaction with having large flocks of cranes on their farms and ranked cranes as the most problematic species, ahead of pests such as Egyptian and Spur-winged Geese. Although most farmers reported that deliberate poisoning was not a problem, if levels of damage continue this may become a larger threat to cranes in future. The Overberg region does not seem to require as urgent intervention, although options should still be presented as some farmers did indicate that cranes feeding at feed troughs were a problem. Farmers in this regions expressed greater tolerance for cranes, potentially as a result of exposure to cranes or conservation initiatives. This research highlights that attitudes and tolerances to damage are location and context specific and that investigations into the severity and nature of the perceived problem is vital if appropriate mitigation is to be introduced.

Chapter 2

Survival and movement of Blue Cranes in the Western Cape of South Africa

Introduction

A population's viability derives from basic demographic parameters of reproduction and survival. The overall viability of the Western Cape population of Blue Cranes has been explored in a population viability assessment comparing the three major populations in South Africa (McCann et al. 2001b), however the survival rates used in this study were based on the expert opinions of conservation authorities rather than empirical estimates. The only study examining survival rates, based on capture-mark-resighting and dead-recovery models, explored the effect of rainfall on reproduction and survival of Blue Cranes in the Nama Karoo (Altwegg & Anderson 2009). Their study found that crane survival increased with rainfall in the late breeding season, and estimated survival to be 0.53 in their first year, 0.73 their second and third years and 0.96 for older birds. Although survival of the Western Cape population of Blue Cranes has not been estimated directly, the fact that rainfall is higher in the Western Cape compared to the Nama Karoo and that there is a high abundance of food on agricultural lands, may lead to a higher survival rate in the Western Cape.

A number of different factors can affect a species survival: year, season, age, sex or environmental variables can all cause variation in survival probabilities (Lebreton et al. 1992). For example, animals of different ages are often expected to differ in their probabilities of survival (Seber 1971), with juveniles expected to have reduced survival compared to adults due to naivety and inexperience (Caswell 2001). Survival can vary with time if the population faces different conditions between years (for example: Cézilly et al. 1996; Peach et al. 1994). Migrants or local populations within a metapopulation that visit or inhabit geographically separate habitats and thus experience varying environmental conditions, will also have differential survival rates (Schaub et al. 2012; Gruebler et al. 2014). The work of Altwegg and Anderson (2009) indicates age-structure within the Nama-Karoo population of Blue Cranes and a similar age structure is expected for the Western Cape

population. Location may also be vitally important in determining the survival of cranes, especially because the two areas in the Western Cape that are the focus of our study differ widely in their exposure to conservation initiatives.

The conservation value of the Western Cape's population of Blue cranes is high, but how cranes utilize this landscape and move within the region is unknown. Even small-scale movement patterns of a species are essential to understand, as the extent of their movements will determine their exposure to threats (such as collision mortality and persecution) and their spatial use of resources (Higuchi et al. 2004). Movement patterns can also offer the potential to understand larger-scale population processes that arise as a consequence of individual behaviour and fine-scale environmental heterogeneity (Patterson et al. 2008). Individual movements are dominated by interactions between life history, behaviour, habitat and physiology (Patterson et al. 2008). The challenge of sorting biological signals as a result of these interactions from observational errors is very complex, and each observational technique comes with its own errors. For example, mark-release-recapture (the technique used in this study) is susceptible to variation in recapture effort, biases in sampling techniques or behavioural reactions of the animals to being observed (Devineau et al. 2006), and only informs where a bird was resighted rather than the route it took to get there (McCann et al. 2001).

Knowledge about the extent of Blue Crane movements is also useful in order to get accurate estimates of demographic parameters such as survival and population size (Horton & Letcher 2008; Drake et al. 2001). Movement is fundamental in the dynamics of fragmented populations as it can connect populations through processes such as emigration and immigration (Ims & Yoccoz 1997), and therefore correctly identifying the pattern of these movements in study populations is vital for the interpretation of parameters such as survival. Heterogeneity in recapture probability is also likely a result of both permanent emigration and local movements within and out of an individual's home range (Horton & Letcher 2008). Therefore the results of investigations into movement patterns (including site fidelity, home ranges and permanent emigration) will likely significantly improve the reliability of research into demography and viability of Blue Cranes.

The two sub-populations in the Swartland and Overberg regions of the Western Cape experience very different levels of conservation: the Swartland population has had little conservation attention, while the Overberg population has been the focus of numerous conservation initiatives. If there is significant movement between regions however, the focus will need to shift to a larger scale. On a broad scale, the Western Cape population is thought to be more sedentary than populations in the eastern part of the country (McCann et al. 2001). Blue Cranes establish breeding territories during spring and summer but by late summer the pairs and their offspring aggregate to form flocks (McCann et al. 2001). Very little is known about the movements of these flocks during winter. At this stage formal investigation into movements of Blue Cranes has been restricted to a three year study of 10 birds from different areas of South Africa using satellite tracking (McCann et al. 2001). It was found that Blue Cranes generally made small movements within their regional areas, and in the eastern part of the Country made movements along an altitudinal gradient between winter and summer. These findings were however limited by the small sample size, the short-term nature of recordings and relatively inaccurate readings due to the tracking technology used. Studies have also attempted to explore Blue Crane movements via bird atlas and CAR count data, but the seasonal flocking behaviour and changes to group sizes at different times of the year means that this type of data should be interpreted with caution (Allan 1997). This chapter uses resightings of a large number of marked individuals over a period of 18 years to explore how far, in what season (breeding/non-breeding) and at what age cranes make movements (if any) within the Western Cape.

In this chapter I use a long-term dataset to explore survival and movement patterns, two important and relatively understudied components of Blue Crane demography and population dynamics. Although both components are important to explore individually, in combination they are even more powerful. Survival estimates are intrinsically linked with movement patterns of individuals, as uncertainty as to levels of immigration, emigration and fidelity of the study population will limit the accuracy of these parameter estimates (Cooper et al. 2008). Therefore examining movement patterns, even in a rough way, will contribute towards improved estimation of vital demographic parameters such as survival.

Methods

A total of 649 Blue Cranes were marked in the Western Cape between 1997 and 2015. Each bird was fitted with four to five coloured rings and a numbered metal ring on their upper legs, allowing each marked bird to be individually identifiable. If a bird loses even one colour ring however, it is not possible to accurately identify it and so such resightings were not recorded. Most birds were marked as juveniles (96%), with only 27 of the 649 marked as adults. The number of birds marked in the Overberg/Agulhas plain (n=591) was far larger than the number marked in the Swartland (n=48). Ten birds did not have a ringing location recorded and were excluded from analysis of natal movements. Birds were resighted opportunistically by conservation workers and added to a central database managed by Kevin Shaw of CapeNature. Every time a bird with a complete set of colour rings was resighted, the bird was identified using these colour rings and the date and location was recorded (GPS used for most sighting locations, very occasionally the farm name and area noted and GPS coordinates added later). Resighting effort varied strongly over time and among areas, as the Overberg region is where crane conservation officers were based for several years. Birds of less than one year were classified as juveniles, birds of 1-3 years as immatures and birds of more than 4 years as adults. Sighting date were classified as non-breeding (March-August) or breeding (September-February).

Survival estimates

I examined survival of Blue Cranes in the Western Cape using mark-resighting models in the programme MARK (White & Burnham 1999), based on 698 resightings of 649 marked individuals. These sightings were used to create capture histories for each individual, consisting of 0's and 1's, indicating no sighting or sighting of the individual in a time period. Specifically, I wanted to explore the effect of age, area (Swartland or Overberg/Agulhas plain) and time (in years) on survival probability, and the effect of time and age on resighting probability. I examined four age effects, distinguishing between two age classes (1-3, 4+), three age classes (1, 2-3, 4+), four age classes (1, 2, 3, 4 and older) and an alternative four age structure (1, 2-3, 4-6, 7+). Area was used as a grouping factor in some models: each individual was classified as belonging either to the Overberg/Agulhas Plain or to the Swartland group based on where marking and resightings occurred. If an individual

was seen in both areas, the area where it was marked was used as the group, although this occurred in only 13 of the 649 individuals.

Model selection started with the most general model, which included year-dependent survival and resighting (Φ (t) *p* (t)). A goodness-of-fit test using the median-ĉ method in MARK indicated that the starting model fitted the data well and overdispersion was low (estimated ĉ =1.175, SE = 0.006). A median-ĉ of less than 3 indicates that the data is adequate for analysis using this method (Lebreton et al. 1992) . This estimate was used to adjust Akaike's Information Criterion for over-dispersion (QAICc) (Burnham & Anderson 2002). A sin link was used in all models. The best model was selected based on the lowest QAICc value, and the QAICc weights, which gives the relative support of each model compared to the other models, were examined. Goodness of fit tests were performed in the programme RELEASE (Burnham et al. 1987), where a model is compared to a fully parameter-saturated model in order to assess whether all marked animals have a similar probability of recapture/resighting and if survival differs between newly marked and previously marked individuals (Cooch & White 2015).

Survival estimates using all data available resulted in estimates that were unlikely for adult survival (<0.6). Such low adult survival is unlikely because all other literature indicated a growing and healthy population in the Western Cape (McCann et al. 2001; Shaw 2015). I suspected that lack of resighting effort in some areas might have led to birds effectively becoming unobservable. This cannot be distinguished from death with the available data, and so a subset of the data was created. Marking and resighting points taken in the Eastern Agulhas Plain were excluded because of a lack of resighting effort. Points after 2008 were also excluded as very few individuals were marked or resighted after this time. This subsetted data resulted in slightly more plausible estimates of adult survival. It was not possible to use the approach of Lebreton & Cefe (2002) where a core area of marking and resighting events was defined and survival inside and outside of the core analysed separately, because there were four main areas where marking (Figure 5) and resighting occurred. Analysing survival of four core areas and the survival outside of each using a multi-state approach was beyond the scope of this project.

The survival estimates from the best model were used in a Leslie Matrix (Leslie 1945; Caswell 2001), a common way of exploring population demography. This method allows an estimation of the population growth rate (λ) based on survival and fecundity of different age classes. Three age classes were used as found in the top model, corresponding to juveniles (year 0-1), immatures (years 1-3) and adults (4 years and older). The model simulated females only. A crude birth rate (B_x) of 0.53 was used, which corresponds to 1.06 chicks fledged per pair per year (Aucamp 1996). This was then used to find fecundity (F_x), which is the survival of the age class estimated using MARK (S_x) multiplied by the crude birth rate: $F_x = S_x * B_x$. Females were assumed to start breeding at age four and live up to 25 years old (McCann et al. 2001b). A one-year projection interval was used, and the model was assumed to be density-independent. Survival estimates from the top MARK model were used for each age class. This matrix was then modified iteratively to find the minimum adult survival needed for a positive population growth rate ($\lambda > 1$).

Movement

In order to examine both intra- and inter-regional movements all resightings recorded for all individuals were assigned to one of four areas: Caledon, Bredasdorp, Swartland or eastern Agulhas Plain (Figure 5). This was because both marking and resightings were strongly clustered in these areas. All individuals who were ringed as juveniles and had their ringing location recorded were used to find how far Blue Cranes travel from their natal point. This would give an indication of how Blue Cranes disperse through the landscape at different ages. Individuals were said to have returned to or remained by their natal point if the resighting point was within 10 km of the point where they were ringed as juveniles. A central point (centroid) for each individual bird was also found by calculating the average longitude and latitude of all sightings. This centroid was calculated in order to examine how far each location where the bird was sighted was from a central point.

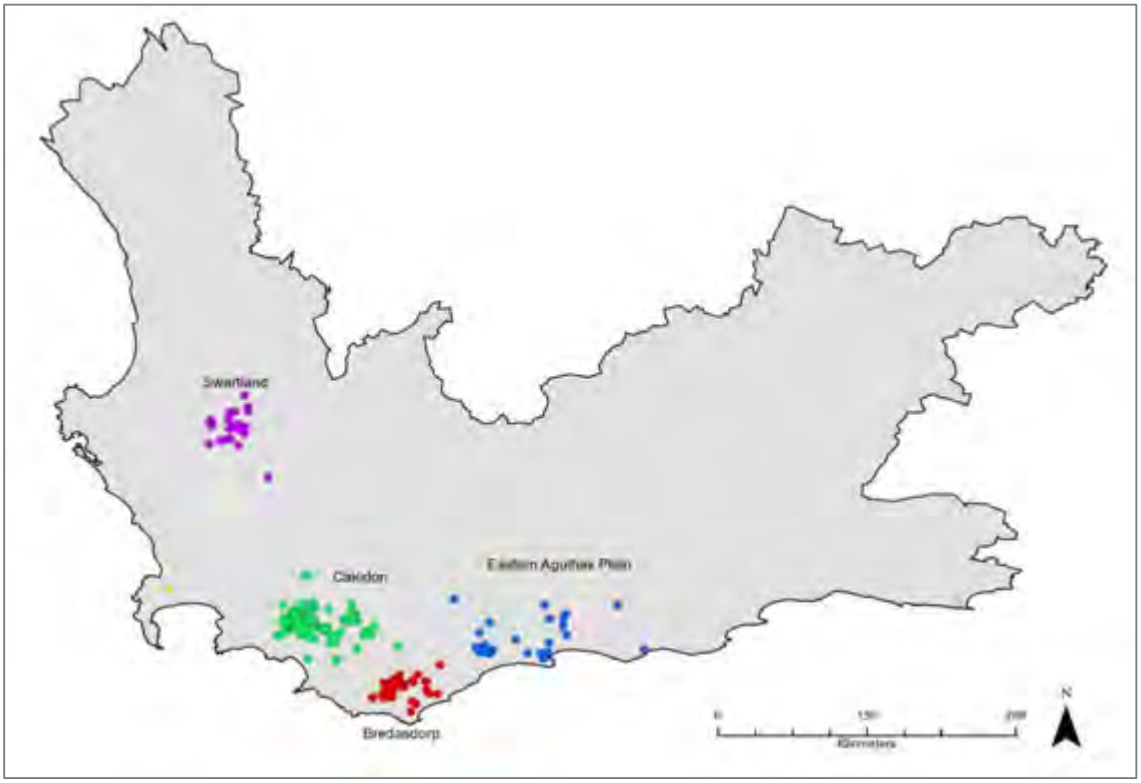

Figure 5: Marking locations of Blue cranes in the Western Cape Province, South Africa. Birds were marked in four main areas: Swartland (n=48), Caledon (western Overberg, n=432), Bredasdorp (eastern Overberg, n=99) and eastern Agulhas Plain (n=60).

Distances from individual natal sites and from centroids were analysed for trends in movement using a linear mixed model in R (R Core Team 2015) to analyse how distance varied according to age (juvenile, immature or adult) and season (non-breeding or breeding). The identity of the bird was added as a random term to account for non-independence of resightings of the same bird. The distance from centroid and the distance from natal point were zero-inflated and non-integer in format, and so a number of different distributions were tested, including normal following log transformation, quasi-Poisson and gamma. Residuals of the fitted models indicated that the distribution of the data following log transformation ($\log_{10}(x+1)$) approximated a normal distribution. The function "lmer" in the package "lme4" in programme R was used to perform the mixed model. An ANOVA was then performed on the model in order to estimate the significance of each variable. Post-hoc Tukey tests were performed on the age variable. The number of resightings for an individual was compared to the maximum distance from its centroid in order to assess the influence of the number of resightings on this parameter.

In order to gain a better understanding of general movement patterns, individuals with six or more records were examined in detail. It was not possible to examine all 311 birds resighted for these patterns, and so a subset was taken. This cut off was relatively random, but used because it yielded a manageable yet still informative amount of individuals (n=35). Their records were plotted according to age and season and examined for trends. These individuals could then be classified as moving at a local scale only, moving regionally (moving within the Overberg/Agulhas Plain or within the Swartland) or interregional (moving between the Overberg/Agulhas Plain and Swartland). It was also recorded whether individuals returned to a starting point following a movement.

Results

Survival estimates

The analysis of resighting histories for Blue Cranes marked between 1997 and end 2008 using the program MARK (White & Burnham 1999) allowed estimates of both survival (Φ) and resighting (*p*) probabilities. Model selection favoured a model that distinguished survival (Φ) between three age classes, with year-dependent juvenile survival (Figure 6). Resighting probability (p) was also year-dependent (Figure 7) and differed between areas (model 18, Table 4: Φ (t/. /.) *p* (Area t)). The top model weight was 96.8%, while the next best-supported model (model 9, Table 4) had only 1.6% support. According to the top model, average juvenile survival was 0.601 (95% CI: 0.26-0.84), immature survival (years 2 and 3) was 0.870 (0.72-0.95), and adult survival (4 and older) was 0.715 (0.60-0.81). Resighting probabilities decreased steadily over time, with an average probability of 0.29 (0.20-0.41) on the Agulhas Plain and 0.12 (0.014 to 0.64) in the Swartland.

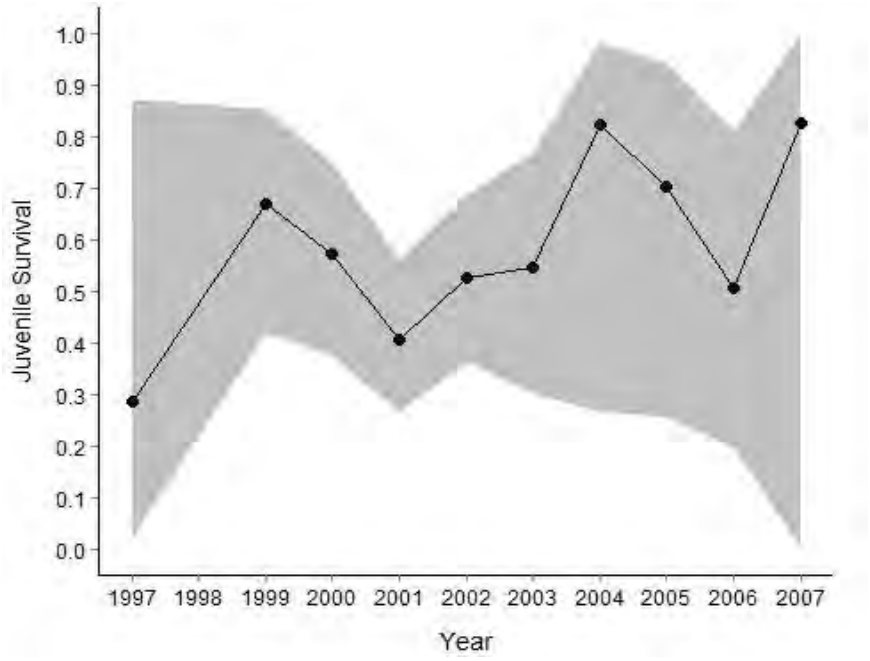

Figure 6: Inter-annual variation in juvenile Blue Crane survival probability in the Western Cape, which corresponds to yearly intervals between 1997 and 2008. The shaded area shows the 95% confidence interval for estimates (based on model 18 in Table 4: Φ (A3 t/./.) *p*(Area t)). The interval between 1998 and 1999 was inestimable.

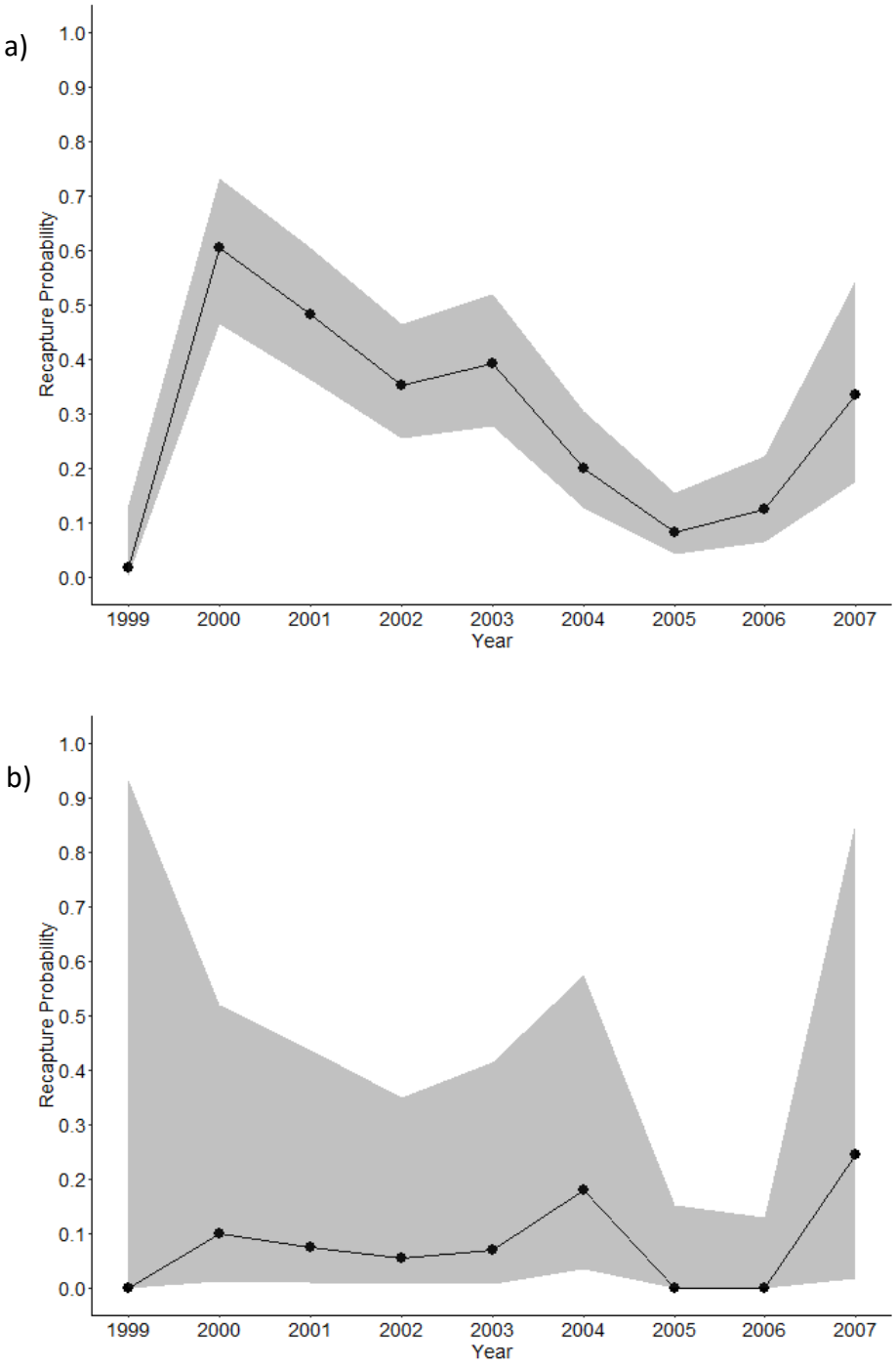

Figure 7: Variation in annual resighting probability of Blue Cranes in a) the Overberg and b) the Swartland regions of the Western Cape, which corresponds to yearly intervals between 1999 and 2008. The shaded area shows the 95% confidence interval for estimates (based on model 18 in Table 4: Φ (A3 t/./.) *p* (Area t)). The survival estimate of the interval between 1997 and 1999 was inestimable and thus not shown.

Table 4: Summary of model selection for Blue Crane survival in the Western Cape. Models consist of two parts describing survival (Φ) and resighting (*p*) probabilities. The effect of time, age and area on both survival and resighting are presented. A2, A3, A4 and A4* represent different age structures explored (A2: years 1-3, 4+; A3: 1, 2-3, 4+; A4: 1, 2, 3, 4+; A4*: 1, 2-3, 4-6, 7+). Area used as a group effect (AR: individuals classified as either Overberg/Agulhas Plain or Swartland).

Model type	Model num.	Model	QAICc	ΔQAICc	QAICc Weights	Model Likelihood	# Par	Q Deviance
General	1	Φ (t) *p* (t)	1461.1	16.3	0.000	0.000	21	231.3
	2	Φ (AR) *p* (t)	1461.4	16.6	0.000	0.000	13	248.3
	3	Φ (t) *p* (.)	1535.6	90.8	0.000	0.000	12	324.6
	4	Φ (.) *p* (.)	1573.8	129.0	0.000	0.000	2	383.1
Φ (Age) *p* (time)	5	Φ (A3 ././.) *p* (t)	1463.5	18.7	0.000	0.000	14	248.4
	6	Φ (A4 ./././.) *p* (t)	1465.2	20.4	0.000	0.000	15	248.0
	7	Φ (A4*./././.) *p* (t)	1465.2	20.4	0.000	0.000	15	248
	8	Φ (A2 ./.) *p* (t)	1470.5	25.6	0.000	0.000	13	257.4
Φ (Age*time) *p* (time)	9	Φ (A3 t/./.) *p* (t)	1453.0	8.2	0.016	0.017	21	223.2
	10	Φ (A2 t/.) *p* (t)	1458.3	13.5	0.001	0.001	23	224.3
	11	Φ (A4 t/././.) *p* (t)	1461.2	16.4	0.000	0.000	25	222.9
Φ (Age*Area) *p* (time)	12	Φ (A3 AR ././.) *p* (t)	1454.7	9.9	0.007	0.007	17	233.3
	13	Φ (A4* AR ./././.) *p* (t)	1456.6	11.8	0.003	0.003	19	231.1
	14	Φ (A2 AR ./.) *p* (t)	1459.9	15.2	0.001	0.001	15	242.7
Φ (Age *Area*time) p (time)	15	Φ (A3 AR t/./.) *p* (t)	1457.4	12.6	0.002	0.002	30	208.5
	16	Φ (A2 AR t/.) *p* (t)	1458.7	13.9	0.001	0.001	30	209.8
	17	Φ (A4 AR t/././.) *p* (t)	1461.4	16.6	0.000	0.000	32	208.2
Φ (Age *time) p (Area *time)	**18**	**Φ (A3 t/./.) *p* (AR t)**	**1444.8**	**0**	**0.968**	**1.000**	**27**	**202.3**
Φ (Age*[Area]* [time]) *p*(Age*[Area]* [time])	19	Φ (A3 t/./.) *p* (A3 AR t/./.)	1535.3	90.5	0.000	0.000	31	284.2
	20	Φ (A3 t/./.) *p* (A3 t/./.)	1539.4	94.6	0.000	0.000	25	301.2
	21	Φ (A3 AR t/./.) *p*(A3 AR t/./.)	1542.9	98.1	0.000	0.000	36	280.9
	22	Φ (A3 AR t/./.) *p*(A3 AR ././.)	1565.5	120.7	0.000	0.000	25	327.3
	23	Φ (A3 AR ././.) *p* (A3 ././.)	1566.0	121.2	0.000	0.000	9	361.2

Although the top model appeared to provide a reasonable fit to the data and ĉ of the general model was small, the goodness of fit test performed in RELEASE indicated a violation of the assumption of the CJS model that every marked animal in the population has the same probability

of resighting (Test 2: χ^2=29.42, df=17, p=0.031). The assumption that every marked animal in the population at time *t* has the same probability of survival at time *t+1* was not violated (Test 3: χ^2=20.77, df=16, p=0.187). Upon closer examination the test for the resighting data of the Overberg group was found to be significant (χ^2=28.48, df= 15, p=0.018), but not the Swartland group (χ^2=0.936, df=2, p=0.62), although the Swartland data was very sparse, allowing tests on only two occasions. Examination of the deviance residual plot generated by program MARK for the top model did not indicate a lack of fit, as there was no apparent trend in the pattern of the residuals. Therefore, although this model did violate the RELEASE goodness of fit test for resighting, based on the small ĉ value and the result of Test 3 in RELEASE (generally known as the test for the survival parameter) there is reason to accept this model as acceptable given the time constraints of this project. The resighting parameter *p* seemed to be the cause of whatever lack of fit there was in the model.

Using the survival estimates of the top model in a Leslie matrix resulted in a negative population growth (λ) of 0.93 and thus a declining population, contrary to all other literature on this population. According to the Leslie matrix model, assuming the average survival estimates for juveniles and immatures, and that the crude birth rate from Aucamp (1996) are correct, adult survival would need to be at least 0.81 in order for the population to have a positive growth rate. This is attained by the Swartland estimate for adult survival but not in the Overberg (S_{ad} 0.71), although the Swartland population would also be declining due to very low survival of juveniles.

In order to try and account for the low survival estimates seen in the models the rate of ring loss was examined by plotting the maximum age of all individuals (date of last resighting−marking date) (Figure 8). This figure shows a roughly linear slope, which indicates a steady attrition of individuals regardless of age. Survival should increase after the first six months to a year, and the graph should follow a sigmoidal shape typical of long-lived species. This is not apparent however, which may signify a constant and random tag loss rate exacerbated by the large number of tags per individual. Recent observations show that a high proportion (perhaps 80%) of ringed cranes have lost at least one colour ring (P.G. Ryan pers. comm., 20/01/2016), therefore tag loss rather than mortality seems to be driving the pattern seen in this population. Additionally there does seem to be a drop

off of individuals after about 10 years. The alternative four age model, where survival of adults older than 7 years was estimated separately (Table 4, Model 13), seems to support this. Adults in the Overberg under 7 years had a survival of 0.71 (0.59 to 0.81) and those older than 7 years that of 0.67 (0.38 to 0.87). The Swartland adults were not estimable due to sparse data. This gives some indication that MARK may indeed be underestimating adult survival, as well as strongly influenced by ring loss.

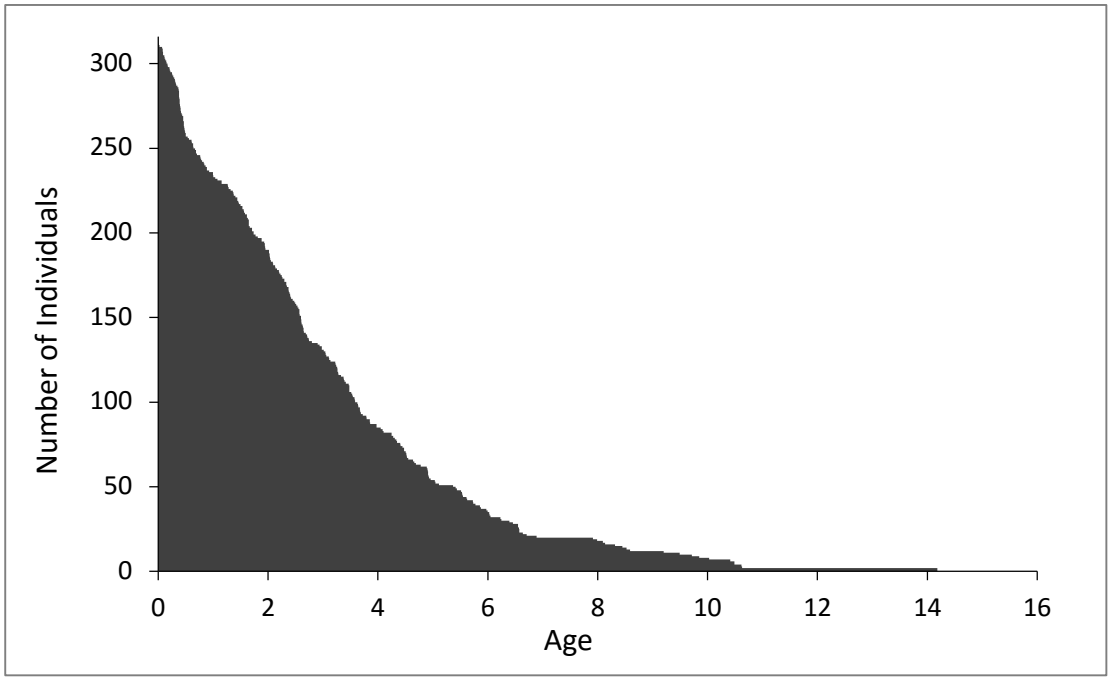

Figure 8: Maximum age recorded for each Blue Crane individual in the Western Cape resighted at least once.

Movement

Of the 293 individuals ringed as chicks that were resighted (45.2% of all individuals marked), 44% dispersed less 10 km, 46% dispersed more than 20km and 10% dispersed more than 100 km from their natal site. The average displacement (± SD, median) from an individual's natal point was 24.58 (± 37.31, 5.61) km. Juveniles were resighted the shortest distance from their nest site (19.4± 34.2, 3.5 km), followed by immatures (23.5± 36.6, 5.8 km) and adults (38.9± 59.4, 11.9 km). The maximum distance from an individual's natal site was not strongly related to the number of resightings, which indicates that birds with even a few resightings still provide useful information to

infer movement patterns and thus all resighted individuals were used in mixed model analysis. The model indicated that distance from natal site (log transformed) varied significantly with life stage (χ^2=33.070, p<0.001) but not with season (χ^2=0.110, p=0.740). A post-hoc Tukey test found that all age classes differed significantly in natal dispersal (juveniles < adults, z=-5.645, p<0.001; juveniles < immatures, z=3.915, p<0.001 and immatures < adults, z=-2.943, p=0.009). There was no difference in distance to natal site between summer/breeding (24.1±38.5 km) and winter/non-breeding (26.4±44.7 km) resighting distances across all age classes.

Distances moved from natal site when adult were only recorded for 77 individuals, as few individuals were resighted as adults. Of these 77 individuals, 39% moved <10 km from their natal site; 46% dispersed >20 km and 38% dispersed >50 km (Figure 9). More than half (57%) of adults returned at least once to the area where they were ringed as fledglings and of the 126 resightings made of these individuals, 48% were <10 km from the natal site. These results indicate that few individuals have been resighted at large distances from their natal site, and that a large number of adult birds return at least once to their natal point (under 10 km from it). Immatures (n=179) followed a similar pattern as adults. Juveniles (n=128) did not travel far from their natal site: only 32% of juveniles were found to move >10km from their point of ringing.

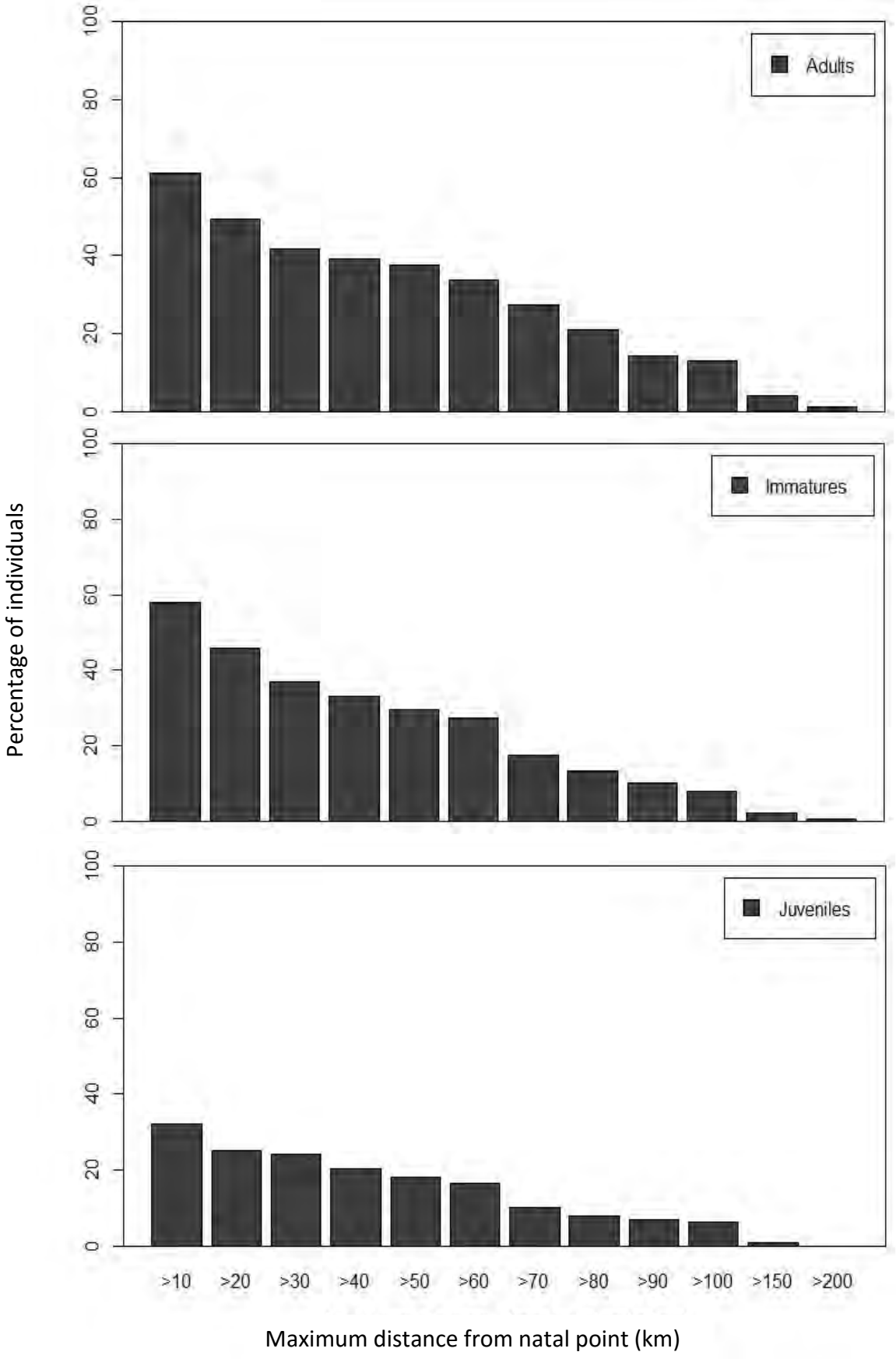

Figure 9: The percentage of Blue Crane individuals who travelled a maximum distance (km) from their natal point, according to age (adult: n=77, immature: n=179 and juvenile: n=128)

Of the 311 birds resighted at least once (47.9% of all birds marked), 51% moved more than 5 km from a central point, 40% more than 10 km, 27% more than 20 km and <1% more than 100 km. The mean (± SD) distance moved from the centroid point was 13.5 ±18.7 km. Similar to natal distance, the maximum distance from the centroid was not strongly related to the number of resightings. Distance from centroid (log transformed) varied significantly with life stage (χ^2=9.34, p=0.009) but not with season (χ^2=2.85, p=0.091), and was significantly less for juveniles (11.2±16.6, median 3.3 km) than adults (18.6±22.9, median 8.5 km; z-value=-2.739, p=0.016). There was no difference between immatures (14.2±18.9, median 6.3 km) and adults or between juveniles and immatures. The mean distance (±SD, median) from the centroid was larger in the non-breeding winter season (15.3±19.6, 7.0 km) than in the breeding summer season (12.1±17.9, 4.3 km) although this difference was not significant.

Of the 311 birds sighted more than once, only 13 (3.8%) moved out of the region where they were ringed as juveniles and only one bird (0.3%) moved out of the Western Cape. Ten of the 13 inter-regional movements were gathered from birds only resighted once, which indicates inter-regional movements are likely to be detected even with only a few resightings. The most prevalent inter-regional movement was from the Swartland to the Overberg, and birds travelling from the Swartland to Caledon occurred in five of the 13 cases (Table 5). There was little movement within the Swartland, but there was significant intra-regional movement within the Overberg: 90% of all movements of >10km were within the Overberg. Most of these movements consisted of birds moving between Caledon, Bredasdorp and the eastern Agulhas Plain (Figure 10). Birds travelling between Caledon to Bredasdorp was the most frequent intra-regional movement, followed by Caledon to the eastern Agulhas Plain. There were relatively few movements between Bredasdorp and the eastern Agulhas Plain. A large number of the resightings did not show any observable movements between areas (Table 5). There was no difference between areas in the number of birds showing no movement, when the number of birds ringed in each region was taken into account (χ^2 =12, df= 9, p=0.21).

Table 5: Count of movements made by Blue Crane individuals (n=311) from four areas within the Western Cape (rows) to each of the other areas (columns). Shaded areas indicate number of times individuals were resighted in the same area as previously (i.e. no movement).

		TO				
		Caledon	Bredasdorp	Eastern Agulhas Plain	Swartland	Eastern Cape
FROM	Caledon	522	35	24	3	1
	Bredasdorp	27	89	9	1	0
	Eastern Agulhas Plain	17	6	39	0	0
	Swartland	5	1	2	6	0
	Eastern Cape	0	0	0	0	0

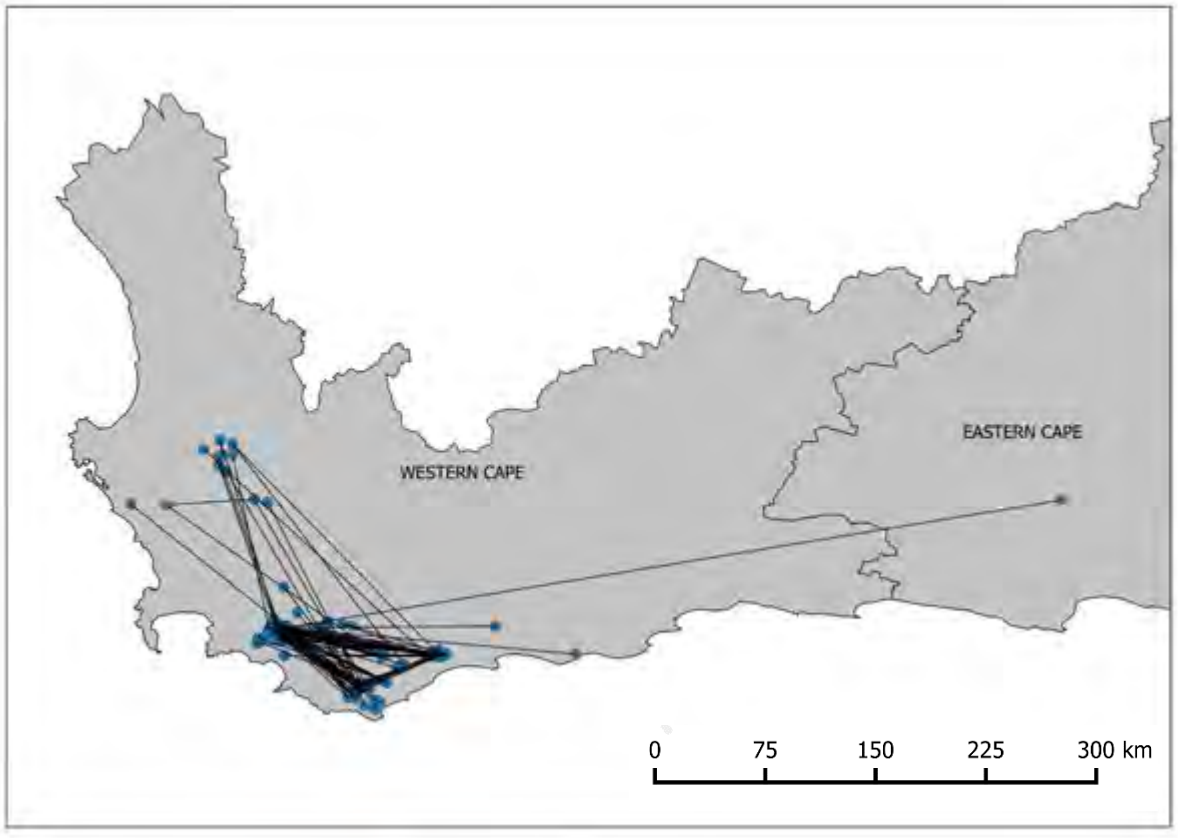

Figure 10: Blue Crane movements of greater than 20km, based on resightings of individuals ringed in the Western Cape (n=62).

Individual examination of 35 birds with six or more resightings allowed a more-in depth analysis of movement. Fourteen birds (40%) only moved at a local scale (< 10 km from their centroid). One bird was ringed as an adult, and of the remaining 13 birds, eight were resighted only as juveniles and immatures. The average distance from the centroid for these locally moving individuals was 3.1±3.3 km.

Of the 35 birds examined in detail, 19 made intra-regional movements between areas of the Overberg, and two birds made inter-regional movements between the Overberg and Swartland. Eight of the 19 intra-regionally moving birds did not have any sightings from when they were adults and two birds was ringed as adults and so only had adult resightings. Figure 11 shows the movements of a random subset (11 of the 19) of these intra-regionally moving birds. Again, the majority of movements were between Caledon and Bredasdorp. Of the 19 intra-regionally moving birds 13 (68%) returned at least once to the area in which they were ringed. Nine of the longer-range (>10km) movements were made when the individual was a juvenile, 22 as an immature and 11 as an adult. Of the 19 birds, 11 made only one large intra-regional movement and then returned to their starting point, while the rest of their movements were relatively localized. The other eight birds made multiple large movements. Back-and-forth type movements seem to be especially prevalent. There was no clear seasonal trend when the three adult birds that made large intra-regional movements were examined however (Figure 11), as these individuals were not recorded consistently in one location at a certain season. The average distance from the centroid for these intra-regionally moving birds was 24.4± 20.2 Km.

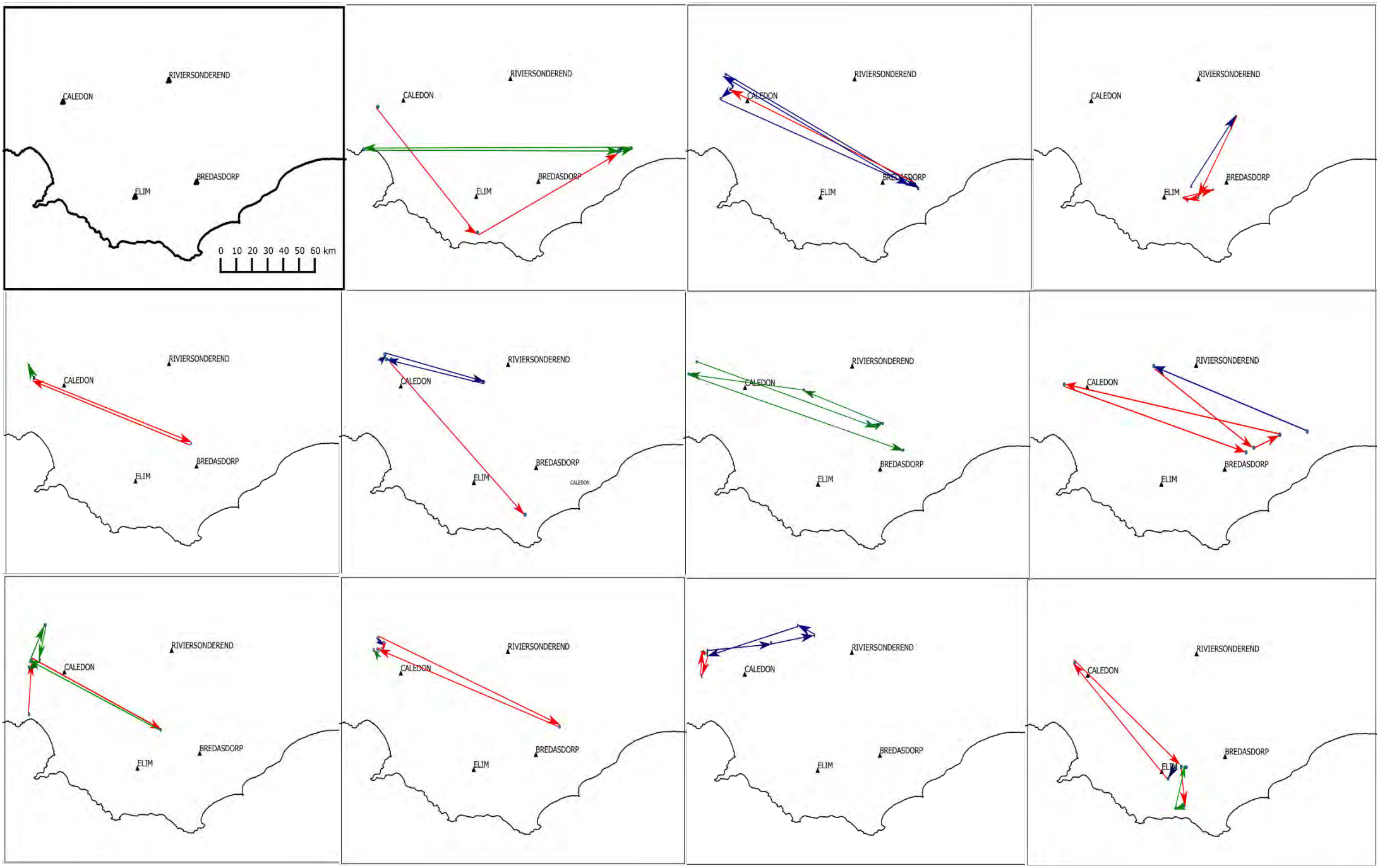

Figure 11: Intra-regional movements of 11 Blue Cranes; blue arrows indicate movements made as juveniles, red as immatures and green as adults.

Discussion

Survival estimates

The estimates for survival of Blue Cranes in the Western Cape generated using mark-resighting methods followed a three age class model, as found in the Nama Karoo (Altwegg & Anderson 2009). The first year survival of 0.60 was similar to the 0.53 estimated by Altwegg & Anderson (2009), and substantially lower than the 0.87 estimated for Sandhill Cranes (Nesbitt 1992). Survival of immature individuals in my study was 0.87, appreciably greater than the 0.73 estimated for the Nama Karoo. Adult survival was only 0.72, much less than the 0.96 estimated by Altwegg & Anderson (2009). Survival of juveniles is frequently lower and more variable when compared to the survival of adults (Redmond & Murphy 2012; McKim-Louder et al. 2013). Juvenile survival can be lower for a number of reasons including smaller body size, increased predation risk, greater energy requirements per unit body size and inexperience (Bender 2008). Although adult survival estimates from my top model seem to be biased low, the pattern of lower juvenile survival compared to older individuals is correct.

There are several reasons why the survival estimates could be different between this study and that of Altwegg & Anderson (2009), the effect of aridity being one of them. Survival for the Nama Karoo Cranes was found to be sensitive to rainfall in this arid area, similar to migratory birds in arid overwintering areas (e.g. Kanyamibwa et al. 1990). The link between rainfall and survival is probably via food abundance (Altwegg & Anderson 2009). Cranes in the Nama Karoo are most often found in natural vegetation (Allan 1995) and are thus likely to be influenced by changes in abundance of bulbs, seeds and invertebrates, mediated by rainfall. The cranes in the Western Cape are unlikely to face this pressure due to the abundance of food resources found on agricultural lands, and their avoidance of natural vegetation (Shaw 2003; Allan 1995). Sheep troughs with feed are available year-round in the Overberg, and especially used during winter, and harvested wheat fields are available November to May (Allan 1995). Food abundance probably peaks in winter in the Swartland when sweet lupin are forming buds, but harvested cereal fields are available as in the Overberg. Therefore the lower survival seen in age class 1 and 2 in the Nama Karoo compared to

my study may be as a result of dry conditions experienced in this region. The higher survival of adults in the Nama-Karoo compared to this study are however biologically inexplicable, suggesting that there may be a problem with my estimates for adult survival.

The problem with the estimates of adult survival from my top models is likely to be as a result of tag loss. An assumption of the Jolly-Seber (Jolly 1965; Seber 1982) type model is that all animals retain their tags and are correctly identified, and the violation of this assumption will limit the utility of this model. Arnason & Mills (1981) found that homogenous tag loss results in a bias of survival estimates, and Pollock et al. (1990) found that the result of tag loss is specifically the underestimation of survival rates. Survival will be even more underestimated if tag loss is not homogeneous. The homogenous tag loss assumption requires that tag-loss is not dependent on the size or age of the animal, or how long the animal has had the tag (retention rate), and is thus fairly restrictive (Mcdonald et al. 2003). Homogeneous tag loss is an acceptable assumption if the expected number of captures and recaptures/resighting is large, and thus when population size is large and capture probability high (Mcdonald et al. 2003). The resighting probability of our top model is on average 31%, markedly less than required for the homogeneous tag loss assumption of >50% in Arnason & Mills (1981). Estimates of survival for long-lived species can be particularly affected by tag loss (Nelson et al. 1980). Therefore, I hypothesise that the ringing system used for Blue Cranes is causing a low resighting probability and negatively biasing survival estimates.

The biased estimate of survival is only correctable if some estimate of tag-loss rate is available (Arnason & Mills 1981), which was not available for our study. Tag loss is commonly incorporated using a multi-state approach (Arnason 1973), which allows the estimation of the probability of moving from a tagged state to an untagged state. Recent advances have developed this approach by incorporating a capture history that corresponds to encounters before tag-loss and encounters after tag loss, thus decomposing survival and recapture conditional on tag retention (Tavecchia et al. 2012). These approaches are reliant on tagging using two separate techniques (e.g. satellite transmitters and wing-tags) or else classic double-tagging. This study did not have any way of estimating tag-loss because no such tagging experiments were undertaken during the ringing process.

The retention rate of the tags obviously depends on type of marker, and although leg rings are assumed to remain on for the lifetime of the individual (Conn et al. 2004), this is very often not the case. A study on Harlequin ducks (*Histrionicus histrionicus*) found that a 6-year old coloured plastic leg ring would be seen 0.5 times as often as a one year old ring, and an eight year old ring would be seen 0.1 times as often (Regehr et al. 2003). Similarly a study on long-lived Giant Canada Geese (*Branta canadensis maxim*) found that 15% of male and 8% of females had lost aluminium leg-rings within 6 years of ringing (Coluccy et al. 2002). Blue Cranes are long-lived (potentially up to 25 years), and so their survivorship curves should be sigmoidal in shape, which is not evident when plotting the number of individuals who survive to various ages (Figure 12). Therefore a relatively constant tag loss is hypothesised, increasing in rate after 10 years.

Blue cranes were originally ringed using two colour rings on one leg to signify area of ringing and one colour ring on the other leg, but after all possible options were used ringers switched to using two rings on the other leg, then three rings, and finally three rings on both legs. These coloured rings were accompanied by a numbered metal ring. Blue Cranes are rarely recaptured however and so the numbered metal ring is in effect only used for identification of dead recoveries: the colour rings are almost exclusively used to record resighting of marked Blue Cranes. Ring loss, colour fading and resighting errors are common problems with the use of colour rings, and even birds with new colour rings can be misidentified (Roche et al. 2014). The chance of not identifying Blue Cranes is quite high because it is often not possible to tell if a bird that has two rings for example, was ringed using two rings or ringed with three and one has been lost. The other problem is that the large number of rings used per individual in the later stages of the ringing program means that there is a high chance that one will fall off and the bird subsequently becoming unidentifiable. If ringing of individuals with field-readable rings were to continue in the future, I would recommend the use of one alphanumeric ring per individual, which have a large unique number and letter combination, rather than combinations of coloured plastic rings. A double tagging experiment, where two identical rings are used on an individual to estimate the probability of ring loss over time, should be attempted for these alphanumeric rings.

Ring loss was however not a problem for the study by Altwegg & Anderson (2009) despite using the same coloured leg rings to mark individuals. Apart from the fact that their study had far fewer resightings than this study (51 vs 698), there are a number of other factors that could result in difference between these two populations. The total number of Blue Cranes ringed in the Karoo (451), was less than in the Western Cape (649). The length of time that ringing was conducted was similar between these areas. The switches in the number of rings used mainly affected the Western Cape population as this was done as colour combinations ran out, and as fewer cranes were ringed in the Karoo and other populations these switches happened far later than in the Western Cape (K. Morrison, pers. comm., 06/02/2016). Because of this, the ring loss which may cause the bird to become unidentifiable (such as ringing with three rings, and the bird subsequently seen with two rings) has been going on for a longer time in the Western Cape than elsewhere.

The negative population growth seen when the estimates for survival were used in a matrix model is contrary to the trends seen from co-ordinated avifaunal road counts (CAR counts). The Western Cape population of Blue Cranes in both the Overberg and the Swartland has however been increasing steadily for a number of years (Shaw 2003; Hofmeyr 2012). Variation in adult survival is likely to contribute strongly to the variation in population growth, as adult survival is an important component of population dynamics in longer-lived species (Schaub et al. 2012). Indeed Altwegg & Anderson (2009) found that population growth in the Nama Karoo Blue Cranes was more sensitive to adult survival than any other age class. Although survival estimates appear to be biased by tag loss (either homogenous or a drop off in retention rate) these estimates allowed the confirmation of Altwegg & Anderson's (2009) age-structured model and also served to alert conservation authorities that the current method of marking cranes has shortcomings.

Movement

The results of the movement analysis indicate that the Blue Crane in the Western Cape are locally nomadic at a small scale: over half of the birds moved less than 20km from their natal point, and the average displacement from an individually-defined centroid was under 15 km. Nearly half of the birds were only recorded as moving less than 5 km from a central point. This is in line with what was suspected by McCann et al. (2007) and Allan (1997). The evidence for this species being local

nomadic is further enforced by the lack of inter-regional movements recorded: only 3.8% of individuals were observed outside of the region (Swartland or Overberg) where they were ringed. Intra-regional movements were more common than inter-regional movements however. Movement between the Caledon and Bredasdorp areas of the Overberg happened quite frequently. The apparently lower frequency of movements among other regions of the Agulhas Plain probably reflect reduced search effort in these areas. Although there was no evidence of a seasonal trend (i.e. moving to a specific location in either non-breeding/breeding or winter/summer), this could be as a result of the coarseness of the data. Seasonal movements along an altitudinal gradient were observed in the eastern grasslands of South Africa, where cranes moved to lower altitudes during winter (McCann et al. 2001). Differences in reporting rates between seasons are however probably due to aggregation into larger and more obvious flocks in winter and dispersal into smaller groups and pairs during summer (Allan 1993).

The evidence of natal philopatry, although probably correlated to the locally nomadic nature of this species, is a novel finding. Juveniles, in their first year of life, moved the least distance from their natal site and were often seen within 10km of their ringing location. This is probably because juveniles leave the territory in which they were born at about 5 months (Aucamp 1996), nearly half of the time when they are classified as juvenile. About 40% of adults were only ever seen at a maximum of 10km from their natal point and nearly 60% of adults resighted returned to within 10km of their natal site at least once. Natal philopatry can occur in migratory species, for example Whooping Cranes (*Grus americana*) exhibit strong natal philopatry at all ages and commonly return to their natal sites following migration (Johns et al. 2005). Knowledge of natal dispersal and philopatry is also vital to understand how non-migratory populations expand. Sex-biased philopatry, where males are more sedentary than females potentially as a result of a resource-based mating system, is evident in Florida Sandhill Cranes (Nesbitt et al. 2002). Having familiarity with an area can give males an advantage and result in less intra-male competition (Greenwood & Harvey 1982). Perennial monogamy, greater dispersal in females and male philopatry are consistent with the male having a role as the primary resource defender, for example defending territories (Greenwood 1980). Blue Cranes are monogamous but it is unknown if males are more philopatric

than females. It was not possible to identify the sex of the Blue Cranes in this study, and so how sex affects movement and philopatry is unknown.

The locally nomadic nature of this species has important conservation implications. The Swartland and Overberg populations should be treated as two local populations within the larger meta-population of the Western Cape, each with their own threats and population parameters. Species conservation needs to take into account dispersal characteristics and temporal changes in landscape structure, something that is often lacking in studies of meta-populations (Fahrig & Merriam 1994). There is significant movement within the Overberg, probably because of the close spatial distribution of the patches (Caledon, Bredasdorp, eastern Agulhas Plain) and ease of dispersal between them. The Swartland is considerably more isolated by both distance and habitat: birds have to cross over the Boland mountain range to arrive there. Dispersers often encounter spatially isolated populations or patches less often, which explains the general lack of movement from the Overberg to the Swartland. Local population dynamics and exchanges between patches are often strongly affected by these types of habitat factors (Ims & Yoccoz 1997). The intra-regional movement of Blue Cranes means that they are capable of recolonizing areas where local populations may have gone extinct. Local populations are generally more at risk of extinction than regional populations via disturbances and demographic factors, but even a small number of immigrants can have a large buffering effect on extinction (Stacey et al. 1997). Therefore although more isolated, the possibility of a small number of birds immigrating to the Swartland from the larger Overberg population means that this population is buffered from extinction, and thus has important conservation implications.

The locally migrant and philopatric nature of this species reinforces the need for farmer tolerance of this species, as one bird may be highly dependent on the fields of one farmer for much of its life. The majority of the Western Cape population is found in unprotected lands (Hofmeyr 2012), and individuals rarely travel out of their natal region. This means that conservation authorities need to give especial attention to farmers with large flocks on their farms, as any intolerance can have a consistently negative effect if individuals utilise an area almost exclusively throughout the year. The regional fidelity of this species does however mean than birds may only be impacted by localised

threats and not face the multiple threats that migratory species do (for example: Higuchi et al. 2004).

These movement findings also have implications for the study of survival as apparent survival estimates are a combination of true survival and fidelity to the study population. A main obstacle in many demographic analyses is uncertainty in immigration rates (Schaub et al. 2012) and this movement data provides a basis for a meta-population model where the Swartland and Overberg regions are treated as separate cores and immigration and emigration between them can then be estimated. High fidelity to a region but not necessarily to a local area would be expected. Natal philopatry suggests that observed survival rates of juveniles are more the result of mortality than permanent emigration, the confounding effect of which commonly limits mark-recapture methods (Cooper et al. 2008). Therefore future modelling of Blue Cranes in the Western Cape can assume high fidelity to a region, with few juveniles permanently emigrating from their natal region in their first year.

Synthesis and recommendations

This study set out to explore the viability and stability of the Western Cape's population of Blue Cranes via investigations into farmer tolerances towards this species, estimation of the important demographic parameter of survival and finally movement patterns and utilization of the landscape. This population of Blue Cranes is not only the largest but also the most stable throughout their range and is thus of conservation importance, considering the "vulnerable"" status of this species. Blue cranes in the Western Cape primarily utilize agricultural lands, and are therefore highly dependent on farmers' tolerances towards them. To date, little research has been done regarding the attitudes of farmers towards cranes, despite the potentially large impact of this factor. There is also a gap in our knowledge regarding basic demographic parameters such as survival, with only one other study conducted in the arid Karoo region, an area which differs substantially from the relatively benign environment of the Western Cape. In addition, very little is known about the movement patterns of this species, even though this may directly impact on their exposure to threats and their ability to persist in isolated local populations. The three components of my study all add to the overall goal of conserving this important population of Blue Cranes.

My findings show that many farmers do perceive Blue Cranes as damaging to livelihoods, but this perception depends on the region, the type of crop farmed and the size of the flocks seen on farms. Tolerances were strongly location specific, and appear to be influenced by the age of the farmer. Even within the Swartland, the region where high levels of crane-caused damage was reported, perceptions and management of this species differed strongly. This reinforces the literature on human-wildlife conflict: perceptions of damage do not have a simple and unilateral relationship to the amount of damage caused, but rather depend on a number of social and context-specific factors. This component of research is limited by a relatively small sample size per region, although it appeared that our sample size allowed sufficient coverage of the overarching themes. It is important that these findings are disseminated to farmers, and further outreach in the form of trial experiments regarding lure fields, "Avipel" or increased contact with outreach officers is recommended.

The finding that survival was underestimated in the models generated from the long-term resighting dataset has important implications. Loss of colour rings means that this dataset is not useful for generating reliable parameters without further information into the rate of ring loss. Thus, conservation authorities require a new approach to marking or else a detailed study into the rate of ring loss: how long colour rings are expected to last, and if certain colours degrade faster than others. Regardless of the apparent problems with this dataset, survival is a vital parameter to estimate, and this study provides a basis from which informed decisions about either ringing strategies or the use of integrated population analyses can be made.

The finding that Blue Cranes are resident to locally nomadic agrees with most of the literature on the subject, although this is one of the first times that empirical data has been used to quantify movement. Blue Cranes appear to exhibit high regional fidelity and immigration into other regions may be relatively limited. Adults returning to the area where they were ringed was observed and is a novel finding, but it is not known if these visits coincided with breeding events and can thus be unequivocally termed “natal philopatry”. The random intervals between resightings does however mean that these data are quite coarse, and although can demonstrate overall movement in a region, does not provide information about the route the bird took to arrive at a point, or how long it took to get to a point. Regardless, it is a first step towards a more sophisticated understanding of movement patterns for this species.

The three components of this study are linked in a number of ways. Firstly, the result that Blue Cranes in the Western Cape are local migrants but exhibit high regional fidelity is linked to farmer perceptions of crane-caused damage. Birds in the Overberg, where farmers do not have negative perceptions of them due to a lack of crane-caused damage, are unlikely to travel to the Swartland where perceptions may be more negative. This may mean that cranes born in the Overberg are less likely to experience persecution, while cranes in the Swartland may face more persecution and are unlikely to emigrate to the Overberg where tolerances are higher. Management of these two populations can therefore be tailored specifically according to the threats they experience and damage they cause. Secondly, the result that farmers in the Swartland may be less tolerant of cranes, combined with different environmental conditions, could translate into the lower juvenile

survival observed in the Swartland. An area effect was found to be important in estimating survival and therefore management of these two populations separately is again reinforced. Finally, movement is strongly linked to survival as the level of site fidelity, emigration and immigration all affect the robustness of estimates. For future analyses the high regional fidelity of cranes can be incorporated into models.

Further research is needed on all three components of this thesis. Firstly, there is a need to explore location-specific damage-prevention strategies. The results point to a need for strategies to prevent Blue Cranes from gathering on sweet lupin fields in the Swartland, and a less urgent need for ways to modify sheep troughs in the Overberg to exclude cranes. I recommend the continued research into substances like “Avipel” as well as the effectiveness of lure fields. Further, I recommend a switch from using multiple coloured plastic leg rings to field-readable alphanumeric rings, along with a double-tagging experiment to estimate the rate of tag loss, as such information could substantially improve the estimation of survival parameter, in addition to the use of integrated population analyses. Finally, there is also a need for fine-scale movement data based on animal-borne GPS tags in order to forward the understanding of movement patterns, and so the use of satellite transmitters is recommended. This would allow an examination into the effect of season on movements, and a better understanding of permanent immigration and emigration.

Conclusion

Our understanding of the viability of the Western Cape population of Blue Cranes is limited by a lack of basic information regarding the attitudes of local farmers and the demography and movement of this species. My findings provide a basic understanding of farmer perceptions towards Blue Cranes, urge a rethinking of the current strategy used to mark this species and have indicated that this population is resident to locally nomadic. Although there are limitations associated with each of the components of this study, there is reason to believe that, given appropriate mitigation for crop damage and further research into both movement and survival parameters, this population has a good chance of remaining a stronghold for this vulnerable species.

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The Harvard (Author-Date) style was used for both in-text citations and bibliography.

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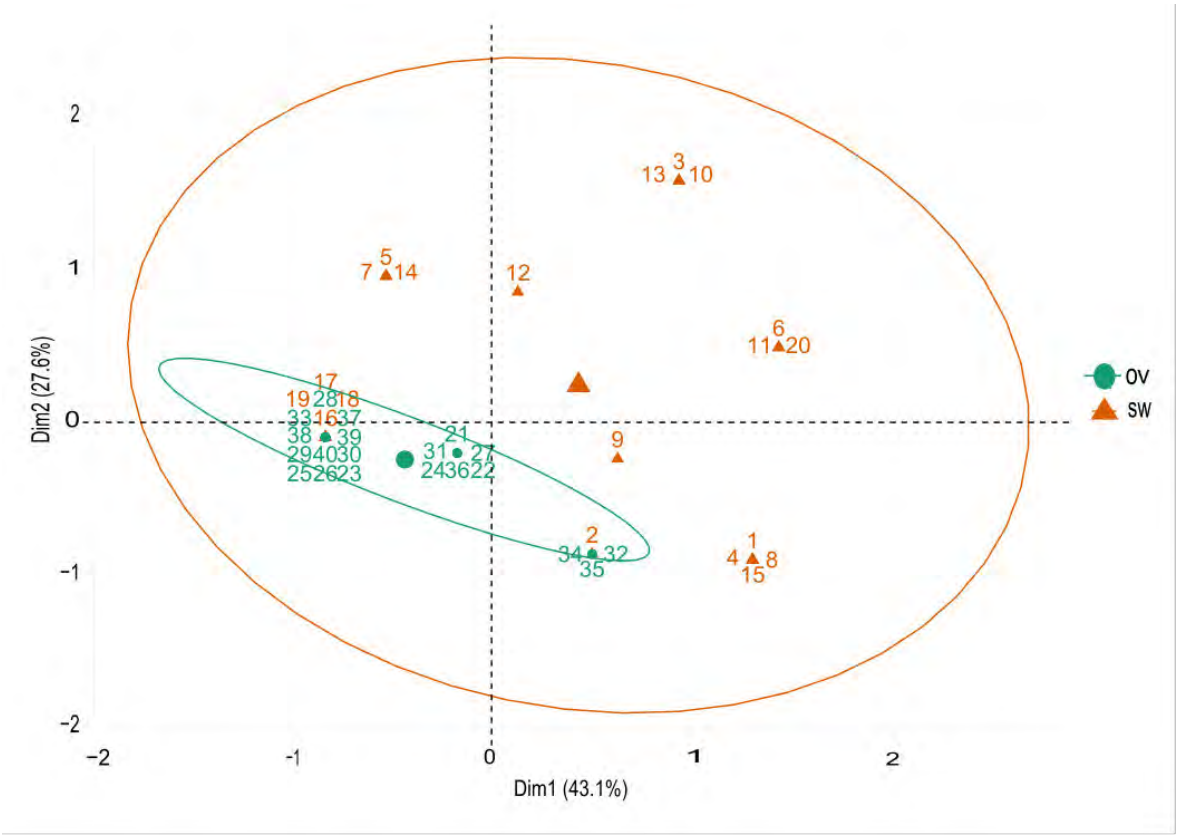
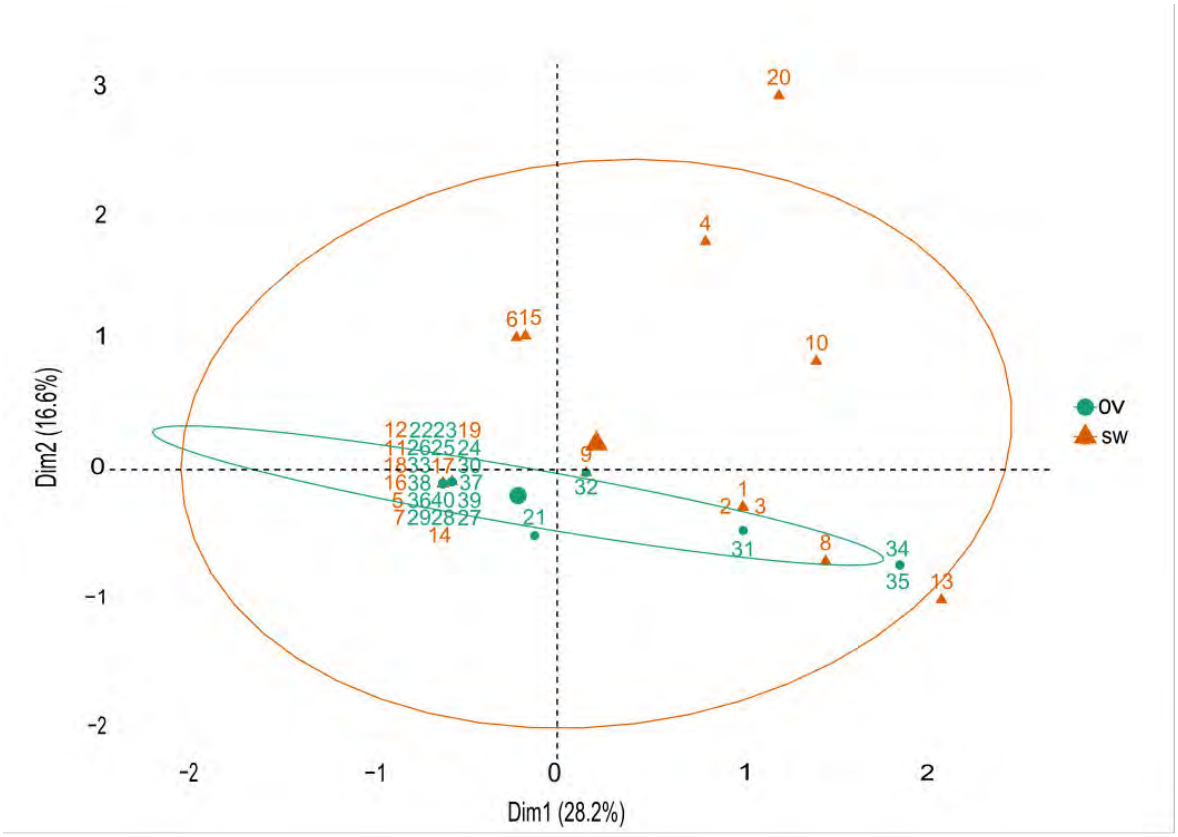
Appendix



Appendix figure 1: Placement of individual respondents from the Swartland (SW; 1-20) the Overberg (OV; 21-40) and) for Multiple Correspondence Analysis of damage perception factors. Smaller symbols indicate individual respondents by region, while the larger symbol indicates the centroid point for those respondents. Ellipses represent the area where points are concentrated for each respondent region.



Appendix figure 2: Placement of individual respondents from the Swartland (SW; 1-20) the Overberg (OV; 21-40) and) for Multiple Correspondence Analysis of attitudinal and management factors. Smaller symbols indicate individual respondents by region, while the larger symbol indicates the centroid point for those respondents. Ellipses represent the area where points are concentrated for each respondent region.

Questionnaire used to investigate farmer perceptions towards Blue Cranes in the Western Cape, South Africa

Blue crane/farmer attitudes interview template for the Swartland and Overberg regions

Please make sure respondent has read and signed a copy of the informed consent form before continuing

Interview number:

1. In what year did you begin farming?

   _____

2. What is your position on the farm? (manager, absentee landowner, owner). Do you farm with someone else (father /son/manager etc.)?

   _____

3. When were you born?

   _____

4. How big is your farm (Ha)?

   _____

5. Please give a detailed breakdown of what you farm. What is the total percentage of each type of crop or land-use out of your whole farm? (Example: 20% barley, 40% alfalfa, 30% sheep pasture, 10% fallow)

Crop type/land-use	% of crop out of total farmland owned

6. Have you changed your major crop type or landuse to something else recently (in the last 2-5 years) and why?

   _____

   _____

   _____

7. Do you think the weather patterns has changed in the last few years, and how has it changed? (Example: less rain in winter, warmer summers, etc.)

   _____

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8. Please indicate for each species below in what context you have seen them on your farm, and rank them in terms of the problem they pose to your farm (1-3).

Species	Seen on farm	Roosts/nests seen on farm	Large flocks seen on farm (20+)	Problem rank
Blue Cranes				
Egyptian Goose				
Spur-winged Geese				
Other?				

9. Are any of these species causing damage and what specifically is being damaged by each of these species?

10. Can you give an estimate of how much damage each species may have done (either in monetary terms, or in % of crop lost/hectare)? How did you decide on this estimate?

11. What months does most of this damage occur in?

12. If your attitude or perception towards cranes has changed recently, can you explain why it has changed?

13. What means have you used to manage cranes and geese on your farm, and how successful are they?

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14. Do you use different methods for cranes and geese?

_____

_____

15. Have you had contact with conservation agencies about any conservation initiative before, in relation to your farm/area?

_____

_____

_____

16. Which of the following ways of dealing with cranes do you find acceptable:

- Tin cans/ plastic streamers
- Culling
- Shooting to scare them
- Poisoning

17. Are there methods that are used in your area that you are uncomfortable with?

_____

_____

_____

18. Would you be willing to explore methods such as lure fields (small strips of land adjacent to your fields planted with a crop cranes find attractive) etc. to manage the cranes?

_____

_____

19. What do you think are problems for cranes? (Examples if say don't know: people taking eggs/chicks, poisoning, chicks getting caught in fences, collisions with power lines)

_____

_____

_____

20. Have you noticed any chicks with a leg problem? If yes, when did you first notice this problem?

_____

21. Do blue crane flocks move around a lot during the day or do they stay in one field?

_____

_____

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