

**Investigating factors that influence the breeding success of the
endangered African penguin (*Spheniscus demersus*) at a mainland
and island colony in the Western Cape, South Africa**



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May 2022

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Plagiarism Declaration

I declare that “Investigating factors that influence the breeding success of the endangered African penguin (*Spheniscus demersus*) at a mainland and island colony in the Western Cape, South Africa” is my own work, that it is not submitted for any degree at any other university, and that all sources I have used have been indicated and acknowledged by complete references.



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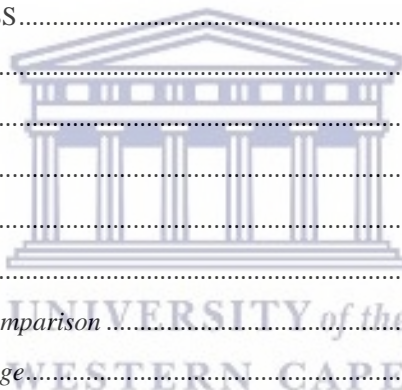


27 May 2022

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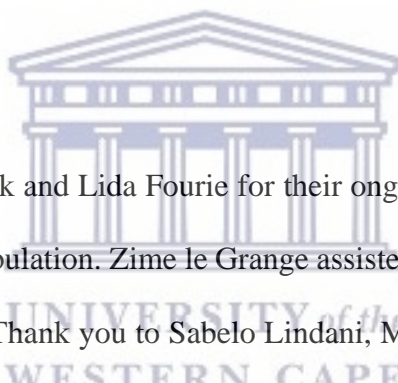
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The logo of the University of the Western Cape, featuring a classical building with columns and a pediment, with the text 'UNIVERSITY of the WESTERN CAPE' below it.

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ABSTRACT

Since the 1950s the global seabird population have declined by 70% and today some penguin species are amongst the most threatened seabirds in the world. The African penguin (*Spheniscus demersus*) population experienced a sharp decline in the twenty first century, which led to the species being listed as endangered in 2010. African penguins are facing a range of threats including limited food resources, habitat degradation, pollution from oil spills and predation.

This study aims to compare the breeding success and chick condition of African penguins at Stony Point and Dyer Island. The study contributes to the analysis of long-term monitoring of demographic data, identified in the Biodiversity Management Plan for the African penguin. The study took place at two penguin colonies in the Western Cape of South Africa. Dyer Island Nature Reserve (island colony) is 8 km from Kleinbaai and Stony Point (mainland colony) is in Betty's Bay. The study made use of data collected for breeding success, chick body condition and fish biomass data for the period 2013 to 2019 for Stony Point and data for the period 2008 to 2019 collected at Dyer Island.

Breeding success was calculated using an extension of the Mayfield method. The body condition of chicks was calculated using the body condition index to assess samples of chicks of various ages and sizes. Fish biomass data obtained from DFFE (Department of Forestry, Fisheries and Environment) was compared with breeding success and chick condition to determine whether there were any significant correlations. The results of the breeding success study (Chapter 2) showed that the mean fledging success and overall breeding success were higher at Stony Point than at Dyer Island. The number of days chicks require to fledge the nest

(fledging period) showed a variation between the years and the colonies. The average fledging period was shorter at Stony Point compared to Dyer Island. At both colonies the fledging period decreased towards the end of the breeding season. The overall breeding success showed a variation between the months, but at both colonies the success rate was low at the start and end of the breeding season. The wooden box nest type was the most successful nest type at both colonies with the highest overall breeding success.

The results presented in Chapter 3 show that the condition index of chicks at Dyer Island was poorer than that of chicks at Stony Point. This suggests that feeding conditions are poorer at Dyer Island. The mean monthly chick condition at Dyer Island showed a decline towards the end of the breeding season, compared to Stony Point where the mean chick condition stayed constant throughout the season. At Stony Point the wooden box nest type was the most successful nest type with the highest mean chick condition, while the natural burrows were the least successful nest type. The vegetation nests had the highest mean chick condition at Dyer Island, compared to the artificial burrows with the lowest mean chick condition.

The results in Chapter 4 indicated that chick body condition at Stony Point was related to local prey abundance as measured by the annual fish surveys; chick body condition of the B-chick increased when there was an abundance in local pelagic fish. At Stony Point there was a correlation between hatching success and fish biomass. The results suggested an increase in hatching success when fish biomass increased. At Stony Point fledging success, however, showed a negative correlation with fish biomass - decreasing when pelagic fish biomass increased.

The loss of African penguin eggs and chicks during the breeding season should be prevented to increase breeding success. The factors influencing mortality should therefore be addressed through management interventions. One important factor is food resources. To address this the competition with purse-seine fishing needs to be limited within the feeding area of the African penguin, and the pressure reduced especially when food supplies are low. Fishing closures around penguin colonies should be considered as a conservation measure to increase the pelagic fish biomass available to forage. Dynamic ocean management (real-time management) should be considered as a measure to increase the efficacy and efficiency of fisheries management by aligning the human and ecological scales of use.

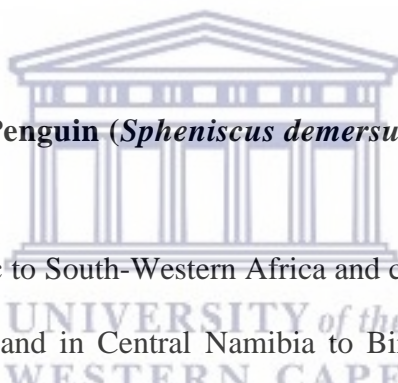


CHAPTER 1 – INTRODUCTION

1.1 Background

The global seabird population has declined by 70% since 1950 and today they are considered to be the most threatened group of birds (Croxall et al. 2012). Some of the penguin species are also amongst the most threatened seabirds (Croxall et al. 2012). Penguin species across the world are facing a range of threats including climate change, habitat degradation, pollution from oil spills, predation, human disturbance, and competition for prey with fisheries (Trathan et al. 2015; Dias et al. 2019).

1.2 Study species – African Penguin (*Spheniscus demersus*)

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The African penguin is endemic to South-Western Africa and currently breeds in 27 localities ranging from Hollams Bird Island in Central Namibia to Bird Island in the Eastern Cape (Hockey et al. 2005). Almost 77% of the overall breeding population resides in South Africa (Birdlife International 2021). In the early part of the twentieth century the African penguin population was over a million breeding pairs globally, but it declined to 147 000 breeding pairs in 1950 (Sherley et al. 2020). In 2021 a historical low of 10 400 breeding pairs were recorded in South Africa (Sherley et al. 2021). The African penguin population has experienced a sharp decline in the twenty first century which has led to the species being declared as endangered in 2010 and the population is continuing to decline (Birdlife International 2021). The National Environmental Management: Biodiversity Act (NEM-BA) of 2004 makes provision for the compilation of a Biodiversity Management Plan (BMP) for any indigenous or migratory species to South Africa (RSA 2004). The first African Penguin BMP was gazetted in 2013 with a 5-year lifespan to halt the decline and promote the population recovery of the endangered

African penguin (DEA 2013). The second version of the plan was compiled in 2019 led by the then Department of Environmental Affairs (DEA).

African penguins face several threats such as predation, loss of habitat and exploitation of fish resources to name but a few (DEA 2013). One of the most significant threats to the African penguin is the lack of abundance and availability of prey (Crawford et al. 2007). African penguins primarily forage on small pelagic fish such as sardine (*Sardinops sagax*) and anchovy (*Engraulis encrasicolus*), but sardine and anchovy are currently at a low combined biomass with the sardine stock considered depleted as these small pelagic fish are also exploited by commercial fisheries (Sherley et al. 2017). Adult, juvenile and fledging penguins are vulnerable to various predators including Cape fur seals (*Arctocephalus pusillus pusillus*), great white sharks (*Carcharodon carcharias*) and isolated incidents of killer whales (*Orcinus orca*) (Johnson et al. 2006; Makhado 2009). At mainland colonies predators can include leopard (*Panthera pardus*), caracal (*Felis caracal*) and even dogs (*Canis lupus familiaris*), (Crawford et al. 1995).

Oil spills are a major threat to African penguins as the oil causes the feathers to clump which breaks down their insulating properties. This causes them to become hypothermic and thus forces them to leave the water and eventually starve to death (Erasmus et al. 1981). The Western Cape has a history of oil spills and large-scale rehabilitation of oiled birds including penguins, has been carried out in the Western Cape by SANCCOB since their establishment in 1968 (Wolfaardt et al. 2009). There are also records of African penguin entanglement in fishing nets and other materials as well as the ingestion of marine debris and plastics (Hockey et al. 2005). The African penguin annual cycle varies from colony to colony, but they all have a peak breeding and moulting season. They are non-migratory, and birds are present at the colonies

all year round (Crawford et al. 2013). African penguins usually breed for the first time between four and six years of age (Whittington et al. 2005). The eggs (usually two in a clutch) are rounded oval and white, becoming darker and stained as incubation proceeds (Crawford et al. 1999). Incubation is shared by both sexes and the chicks are closely attended by adults until around 30 days old, when they are left unguarded and form crèches (Seddon and van Heezik, 1993). Moulting usually takes place annually in early summer from September to January (Crawford et al. 2006c; Wolfaardt et al. 2009). During the moulting process all the feathers are replaced in order that they are in good condition to provide waterproofing and insulation in cold waters while foraging (Crawford et al. 2013).

African penguins historically dug burrows in the hard guano layer, but guano harvesting reduced the amount of substrate available for penguins to burrow (Frost et al. 1976b). As an alternative to guano, African penguins make use of natural burrows, vegetation nests, open nests on the surface and artificial nests of various types (Sherley et al. 2012a). To try and improve breeding success artificial nests have been used in New Zealand for Little penguins (*Eudyptula minor*) and in Peru and Chile for Humbolt penguins (*Spheniscus humboldti*), (Perriman and Steen 2000; Simeone et al. 2010). To increase survival and improve reproductive success, artificial nests have been placed in African penguin colonies with the aim to improve the breeding habitat and breeding success (Pichegru 2013).

This study focused on different types of nests used by breeding penguins at Stony Point and Dyer Island. These nests were classified as under vegetation, natural burrows and artificial nests. At Stony Point the breeding pairs mostly use vegetation nests, defined as shallow scrapes in the ground which are partially or completely covered by vegetation such as Rooikrans (*Acacia cyclops*) and Kinkelbos (*Tetragonia fruticosa*), (Figure 1.1). The amount of cover

provided varies depending on the vegetation type and how much is present during the season. The vegetation nests on Dyer Island are partially covered by *Mesembryanthemum* species. Penguins also dig burrows in the sandy substrate that provides complete cover, these are referred to as natural burrows (Figure 1.2). The artificial nests on Stony Point and Dyer Island are comprised of three types: wooden nest boxes, cement nests and artificial burrows. The orientation and placement varied throughout the colonies; some were placed in the open and others were partially covered under vegetation. Wooden nest boxes are made of 3-mm thick pine plywood with a A-frame design (Figure 1.3). Cement nests are 30 cm high and 2 cm thick in the design of a half pipe (Figure 1.4). At both colonies there are two types of artificial burrows, the fibreglass and resin mesh type and the keraforce insulation material type (Figure 1.5 and 1.6). The floors of all artificial nest types are open to allow water to drain away and allow occupants to dig (Sherley et al. 2012a).



Figure 1.1: Vegetation nests at Stony Point covered by *Tetragonia fruticosa* (source: Zime le Grange).



Figure 1.2: Penguins breeding in natural burrows at Stony Point (source: Zime le Grange).



Figure 1.3: Wooden box nest at Stony Point (source: Zime le Grange).

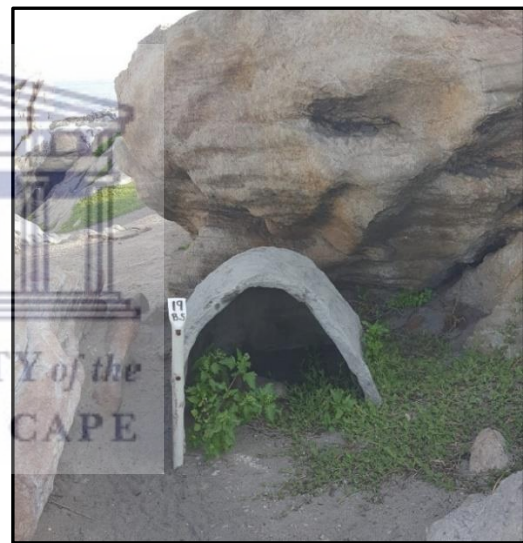


Figure 1.4: Cement nest at Stony Point (source: Zime le Grange).



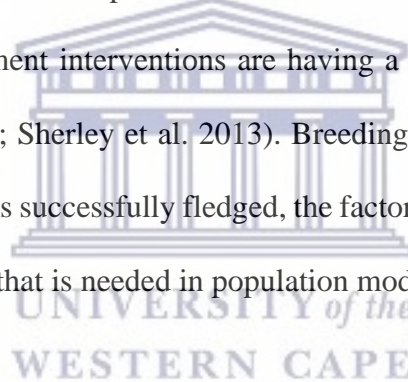
Figure 1.5: Artificial fibre glass nest type at Stony Point (source: Zime le Grange).



Figure 1.6: Artificial keraforce nest type at Stony Point (source: Zime le Grange).

1.3 Breeding success and chick condition

Breeding success amongst seabirds is an important demographic to study since it provides information about the overall health of the population, the parents' overall fitness and ability to provide for chicks as well as the availability of food resources around colonies (Barham et al. 2007; Wolfaardt et al. 2008; Sherley et al. 2013). Successful reproduction will determine the size of a population; if no offspring is produced a population will eventually disappear (Veen et al. 2004). The study of breeding success involves following part of the breeding population throughout the breeding process to determine the fate of eggs and chicks (Veen et al. 2004). Breeding success data can provide information regarding threats impacting on colonies and whether management interventions are having a positive impact on population numbers (Crawford et al. 1999; Sherley et al. 2013). Breeding success data can also provide insight into the number of chicks successfully fledged, the factors influencing breeding success as well as data on productivity that is needed in population modelling (Veen et al. 2004).



Body condition can serve as a useful tool in ecological studies and the management and conservation of wildlife (Labocha and Hayes 2012). It can be useful in detecting conservation needs and to establish conservation interventions (Lubbe et al. 2014). Body condition has been used in various studies focusing on reproductive success, foraging success, and variable environmental conditions (Warner et al. 2016). Animal body condition refers to the proportion of its body mass which is available in the form of metabolizable energy reserves (Jakob et al. 1996). The body condition of birds can be assessed through standard morphometric measurements (Walker et al. 2005). The condition of a chick depends on the ability of a parent to provide food and thus body condition of chicks can be used as an indicator of feeding conditions for parents at sea (Veen et al. 2004). Chick condition in African penguins is

expressed as a condition index based on the relationship between body mass and total head length (Lubbe et al. 2014).

1.4 Study Site

The study took place at two south coast penguin colonies in the Western Cape of South Africa (Figure 1.7). Dyer Island Nature Reserve (34.41°S, 19.25°E) is an island seabird colony 8 km from Kleinbaai (CapeNature 2012). The Stony Point penguin colony (34.37°S, 18.89° E) is a mainland colony located in Betty's Bay (Du Toit and Attwood 2008).

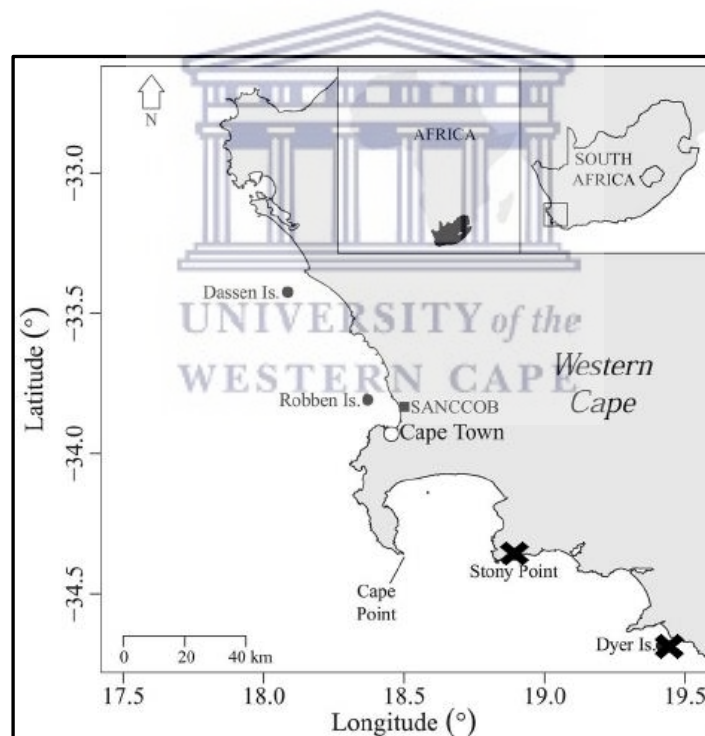


Figure 1.7: Map showing the African penguin breeding colonies in Western Cape, South Africa, including Stony Point and Dyer Island (marked with x), (Sherley et al. 2014b).

1.4.1 Stony Point

African penguins traditionally breed on islands (Crawford et al. 1995). Stony Point one of only two land-based colonies found along the South African coast, is a rocky peninsula within

Betty's Bay on the southern coast, about 75 km southeast of Cape Town. According to Du Toit and Attwood (2008) Stony Point consists of two municipal properties; erven 2411 and 2412, located adjacent to Wallers Drive and Una Drive in Betty's Bay and is about 8.39 ha in size (Figure 1.8).

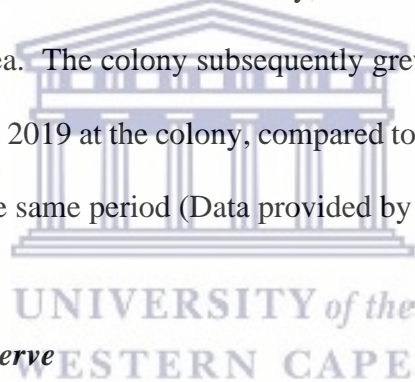


Figure 1.8: Aerial photo of Stony Point penguin colony (Google Earth 2020).

The coastal properties of Stony Point reside within the jurisdiction of the Overstrand Local Municipality, which is located within the Overberg District and are zoned as municipal open space 3. CapeNature, one of the conservation authorities within the Western Cape Province is currently managing the Stony Point colony as per agreement with the Overstrand Municipality. From 1913 to 1936 there was a whale factory operating from Stony Point and the remains of the whaling station can still be seen at Stony Point along with the skeletal wreck of the Una. The Una was used as a cargo and fishing vessel until 1926, when it was scuttled beside the whale station to form a jetty (Du Toit and Attwood 2008).

The vegetation of the area has been mapped nationally at a 1:1 000 000 scale and the Stony Point area falls within the Cape Seashore Vegetation type (Mucina and Rutherford 2006). A

detailed, fine-scale vegetation map was compiled regionally at a 1:50 000 scale for the Vegetation of the Cape Hangklip Area, which includes Stony Point, where the area was described as Coastal plain vegetation (Boucher 1978). Apart from the African penguins breeding at Stony Point the area is also an important breeding site for other seabirds, which includes the endangered Cape cormorant (*Phalacrocorax capensis*), endangered bank cormorant (*Phalacrocorax neglectus*), white-breasted cormorant (*Phalacrocorax carbo lucidus*) as well as the crowned cormorant (*Phalacrocorax coronatus*), (Du Toit and Attwood 2008). The first African penguin nest at Stony Point was found in 1982 and the numbers slowly increased to 35 breeding pairs in 1986 (Whittington et al. 1996). A leopard (*Panthera pardus*) attack in December 1986 reduced the size of the colony, which led to a chain-link fence being erected around the breeding area. The colony subsequently grew steadily over the years with 1702 breeding pairs recorded in 2019 at the colony, compared to 932 recorded at Boulders (the other land-based colony) for the same period (Data provided by CapeNature, July 2020).



1.4.2 Dyer Island Nature Reserve

Dyer Island Nature Reserve lies about 8 km northwest of Kleinbaai, Western Cape. The island is approximately 1 km in length and 200m across its widest point. It is about 20.77 ha in size. Geyser Island is a rocky outcrop of 3.89 ha which lies 150 m southwest of Dyer Island (Figure 1.9). The islands are separated by a channel known as Shark Alley, which is on average 100 m wide and 5 m in depth (CapeNature 2012). Dyer Island Provincial Nature Reserve was proclaimed a Provincial Nature Reserve in terms of Section 6 of the Nature Conservation Ordinance 1974, in the Provincial Gazette of 18 March 1988 by Proclamation No. 23/1988 (CapeNature 2012). Sampson Dyers was the first resident arriving in Dyer Island in 1806 and he worked as a harpoonist for Cloete, Reits and Andersen Company to harvest seals from Geyser Island for their skin and oil (CapeNature 2012).



Figure 1.9: Aerial photo of Dyer Island and Geysers Rock (Google Earth 2020).

According to Mucina and Rutherford (2006) the vegetation of Dyer Island is classified as Cape Seashore Vegetation. This vegetation type includes herbaceous and dwarf-shrubby vegetation, which is often dominated by a single plant species. Dyer Island is listed as one of the 103 Globally Important Bird Areas (IBAs) in South Africa (Barnes 1998). Twelve seabird species have been recorded as breeding on the island including three endangered species, the African penguin, Cape cormorant and bank cormorant (CapeNature 2012). A total of 1071 breeding pairs were recorded at Dyer Island in 2019, compared to 1912 counted at Dassen Island in the same year (Data provided by CapeNature, July 2020).

1.5 Study Aims and Objectives

The African penguin Biodiversity Management Plan identified threats that require action to halt the decline of the species, some of these threats include reduced food availability, loss of habitat, and diseases (DEA 2013). This study was done to contribute to the analysis of long-term monitoring of demographic data, an action as per the Biodiversity Management Plan for the African penguin (DEA 2019).

This study aims to compare the breeding success and chick condition of African penguins at Stony Point and Dyer Island. The objectives are:

- To evaluate the difference in breeding success per year between the two colonies and to evaluate the difference in breeding success per nest type between the two colonies.
- To provide an overview of the overall reproductive success and how the birds respond to different nest types.
- To determine the timing of nest failure per colony.
- To analyse chick condition per year for Dyer Island and Stony Point.
- To provide an overview of food availability at the breeding colonies and the impact of nest type on chick condition.
- To provide management recommendation regarding the improvement of breeding and foraging habitat for African penguins.



CHAPTER 2 – BREEDING SUCCESS

2.1 Introduction

African penguins largely lead an aquatic lifestyle but must return to land to breed and moult (Lustick 1984). Throughout their breeding attempt the birds face a constant trade-off, between how much energy they need to invest in reproduction and self-maintenance (Tveraa et al. 1998). African penguins typically begin to breed at four to six years old (Whittington et al. 2005). Clutches generally contain two eggs, sometimes one egg and on rare occasions a clutch may contain three eggs (Kemper 2006). African penguins can lay a second and even third clutches during a breeding season (Crawford et al. 1999). Parental care is shared between both adults during incubation and chick rearing. The incubation period is approximately 40 days and chicks usually fledge within 55 – 130 days, depending on how well the adults can forage and feed their chicks (Sherley et al. 2013). While the chicks are small the penguin adults will daily alternate their chick guarding and foraging trips (van Heezik and Seddon 1996).

African penguins are non-migratory and there are birds present at the colonies all year round, although the numbers are smaller outside the breeding season. African penguins can breed throughout the year, but seasonal peaks vary between locations (Kemper et al. 2007a). The annual breeding cycle usually starts in February up until September (Sherley et al. 2013). Knowledge of breeding success is important as it influences the population dynamics and conservation status of a species (Wolfaardt et al. 2008). Measuring breeding success involves searching for bird nests and monitoring the outcome, thus providing data on success during egg-laying, incubation and chick rearing stages (Veen et al. 2004). At individual colonies, breeding success as well as data derived during the collection of breeding success data (for example transponder data) can be used as an indicator of the status of the specific population,

local food availability, movement of the colony and site fidelity (Whittington et al. 2005). The breeding success of a penguin colony can be influenced by oil pollution, predation, food type and availability and the type of nest they occupy (Wolfaardt et al. 2008; Pichegru 2013; Sherley et al. 2013). Regular and sufficient food availability is necessary to provide for the energy requirements for chick-rearing, but this can vary during the breeding season and may not meet the energy requirements of a bird (Hamer et al. 2002). Adequate energy reserves are vital for the successful rearing of chicks; if reserves are low seabirds may prioritize their own survival rather than reproduction, thus influencing breeding success (Drent and Daan 1980).

Breeding success can also be influenced by the quality of nesting habitat (Kemper et al. 2007b; Sherley et al. 2012a). African penguins used to dig burrows in accumulated guano for nesting sites, but in the past guano was exploited as fertilizer which led to the removal of guano from islands (Wilson and Wilson 1989). This resulted in penguins occupying suboptimal breeding habitats with many nesting on the surface and being exposed to predators and climatic conditions which can impact the breeding success of the species (Mitrus 2003). Sherley et al. (2012b) found that bank cormorants on Robben Island that bred in exposed nests experienced nest failure during high temperatures and storm events. Cadiou et al. (2009) found that the nesting habitat of European storm petrels (*Hydrobates pelagicus*) deteriorated because of erosion which caused their burrows to collapse. Over several years this resulted in a decrease in breeding numbers.

Artificial nests have been developed and installed in some African penguin colonies to improve their chances of survival (Sherley et al. 2012a; Pichegru 2013). In the past artificial nests formed part of the conservation efforts of threatened seabird species and improved the success rate. The breeding success of the Madeiran storm petrel (*Oceanodroma castro*) tripled over

three successive seasons when using artificial nest boxes (Bolton et al. 2004). Breeding success can be measured in several ways at various phases of the breeding cycle. For example, the proportion of eggs that hatched, proportion of eggs that produced fledglings and the proportion of hatchlings that successfully fledged (Bertram and Murray 2000). Breeding success can be reported as the percentage of eggs or nests in a population sample that has successfully produced young, where egg successes refer to the percentage of eggs that resulted in young that leave the nest, and nest success is the percentage of nests with eggs that produce young that leave the nest (Bertram and Murray 2000).

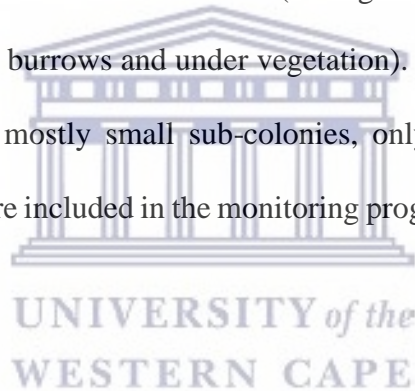
The simplest breeding success ratio is obtained as the ratio of successful nests to the total number of nests monitored (Mayfield 1961). Mayfield (1961, 1975) did, however, develop an alternative method to calculate breeding success. This accounts for the fact that some nests under observation were discovered at various stages of development and not followed to a conclusion. If nests are not observed for their full duration, the observed loss rates are less than the actual loss rates (Mayfield 1975). The Mayfield method measures the exposure in nest-days and calculates the mortality and survival rates at each stage of the nesting cycle. With this method data that would have been discarded in customary analyses can also be incorporated.

The main aim of this chapter was to evaluate differences in breeding success of the African penguin at Stony Point and Dyer Island. The two colonies are geographically close to each other but have experienced diverse populations trends. Understanding these differences could assist with management decision and strategies. The variabilities between breeding years, months (start month of breeding attempt) and fledging period (days from hatched to fledged) were also explored. The study also aimed to determine if breeding success varied between nest types.

2.2 Methodology

2.2.1 Data collection

The data which were used in this study were collected by CapeNature staff between 2013 and 2019 at Stony Point and between 2008 and 2019 at Dyer Island as part of the annual breeding success monitoring programme. The average number of nests monitored yearly at Stony Point was 230 and at Dyer Island 300. During these years, the nest monitoring for both Stony and Dyer Island covered the main breeding season from February to October. The study nests were numbered and marked at the beginning of each breeding season during the incubation phase. Stony Point study nests comprised of artificial nests (fibre glass, wooden boxes, and cement) as well as natural nests (natural burrows and under vegetation). At Dyer Island where most of the nests are surface nests in mostly small sub-colonies, only artificial nests (fibre glass, wooden boxes, and cement) were included in the monitoring programme to prevent disturbance to surface nesting birds.



The nests were checked at an interval of 7 – 14 days. Most of the nests were first visited during the incubation stage, but some nests were monitored for the first time after chicks had already hatched. During each nest visit the number of eggs and/or chicks were recorded. When chicks were present in the nests, they were classified into five development stages (Barham et al. 2007):

P0 - newly hatched chicks with eyes still shut (< 6 days old)

P1 - small downy chicks (about 6 - 15 days old)

P2 - medium to large downy chicks (about 16 - 35 days old)

P3 - large downy chicks (about 36 - 45 days old) and

P4 - chicks with more than half their body in final fledgling plumage (> 45 days old).

The nest content was recorded until the chicks fledged or the nest failed - in the case of the latter the reason for the failure was noted if it was clear what caused it.

2.2.2 Data analysis

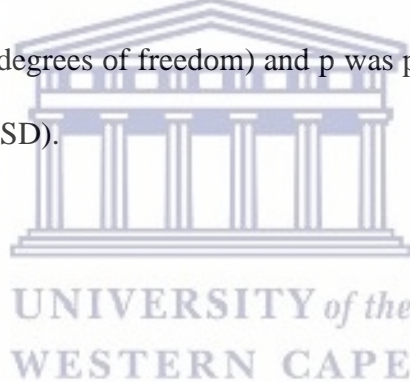
Breeding success was calculated using an extension of the Mayfield (1961) method developed by Sherley et al. (2012a). Only nests that were truly active (i.e., had at least one egg) were included in the calculations. The mid-point between nest visits was used to calculate the total number of days those eggs and chicks were in the nest (Mayfield 1961, 1975). When the hatching date could not be reliably estimated due to long intervals between visits, the estimate of nest-days was constrained so as not to be longer than the maximum interval of 40 days between laying and hatching (Sherley et al. 2012a).

Chicks that reached the P4 stage were considered to have successfully fledged (Sherley et al. 2012a) and if they disappeared after less than 40 days they were considered to have died. Eggs that were incubated for >50 days and did not hatch were considered to have failed. Survival rates during incubation and chick rearing were calculated separately due to the differing mortality rates associated with these two stages (Seddon and van Heezik 1991). Overall breeding success was a combination of the survival rates of the nest contents during both incubation and chick rearing (Sherley et al. 2012a).

The breeding success for each breeding attempt was calculated as the ratio of the number of days the nest survived to the expected number of days for the attempt to succeed (taken as the mean number of days taken by successful nests). Breeding success for unsuccessful nests was capped at 0.95 and for successful nests was taken as 1.00. It is necessary to cap unsuccessful nests at 0.95 because some of these nests might survive for more days than the successful nests,

thus avoiding a survival greater than 1. Overall breeding success was taken as the mean of all the individual breeding successes of the all the nests. Hatching and fledging success rates were similarly calculated from the number of days the eggs or chicks survived. All breeding attempts were treated as independent as the identity of the birds occupying the breeding success nests were unknown, thus it was impossible to determine if it was a second attempt by the same breeding pair.

The Shapiro-Wilks test was used to detect normality. For normally distributed data the student's t-test was used. If the data were not normally distributed, the Kruskal-Wallis H-test was used. A significance level of 5% was used in all tests. For the Kruskal-Wallis tests the values of: H (chi-squared), df (degrees of freedom) and p was provided. Data were expressed as means \pm standard deviation (SD).



2.3 Results

2.3.1 Yearly breeding success comparison

The results from 2799 breeding attempts were used to estimate hatching success at Stony Point for the period 2013 – 2019. Dyer Island results (for the period 2008 to 2019) were from 2972 attempts (Table 2.1). A total of 1879 breeding attempts at Stony Point were used to estimate fledging success and 1669 breeding attempts were used for Dyer Island (Table 2.1). The hatching success showed little variation and no significant difference between the two colonies and between the years. The hatching success varied between 0.84 and 0.95 at Stony Point and 0.81 and 0.97 at Dyer Island. There was no significant difference between the mean hatching success at Stony Point (0.90) and Dyer Island (0.89, Two sample t-test: $t = 1.71$, $p = 0.085$).

Table 2.1: Summary statistics of breeding success per breeding attempt for Stony Point (from 2013 to 2019) and Dyer Island (from 2008 to 2019, no data available for 2014 and 2015).

Year	n = Number of eggs laid	n = Nr of eggs failed	n = Eggs hatched	Hatching success (Mayfield method)	n = Nr of chick failures	n = Nr of chicks fledged	Fledging success (Mayfield method)	Overall breeding success (Mayfield method)	
<u>Stony Point</u>									
2013	443	81	362	0.95	153	209	0.71	0.71	
2014	589	193	396	0.93	142	254	0.77	0.66	
2015	420	186	234	0.90	77	157	0.77	0.58	
2016	533	239	294	0.84	89	205	0.81	0.58	
2017	285	75	210	0.92	77	133	0.77	0.69	
2018	207	67	140	0.86	24	116	0.91	0.70	
2019	322	79	243	0.88	61	182	0.85	0.73	
<u>Dyer Island</u>									
2008	531	304	227	0.86	63	158	0.80	0.52	
2009	644	390	254	0.86	99	132	0.61	0.44	
2010	286	86	200	0.96	43	144	0.83	0.71	
2011	203	80	123	0.94	43	77	0.77	0.64	
2012	381	74	307	0.97	117	170	0.73	0.71	
2013	137	33	104	0.92	46	57	0.72	0.68	
2014				No data available					
2015				No data available					
2016	60	5	55	0.95	15	40	0.92	0.88	
2017	64	42	22	0.89	11	11	0.75	0.52	
2018	247	146	101	0.81	44	56	0.76	0.48	
2019	419	143	276	0.86	95	168	0.77	0.62	

Fledging success showed a large variation between the years and the two colonies. The success rates varied between 0.71 and 0.91 at Stony Point and 0.61 and 0.92 at Dyer Island. The mean fledging success at Stony Point (0.78) was, however, significantly higher than Dyer Island (0.75, Two sample t-test: $t = 2.84$, $p = 0.004$). The overall breeding success per year also showed a large variation between the two colonies and the years. The overall breeding success varied between 0.58 and 0.73 at Stony Point and 0.44 and 0.88 at Dyer Island. The overall mean breeding success rate was significantly higher at Stony Point (0.66) compared to Dyer Island (0.62, Two sample t-test: $t = 8.42$, $p < 0.001$).

2.3.2 Comparison of days to fledge

The fledging period (days from hatch to fledge) at Stony Point was estimated from 1256 attempts during the period 2013 – 2019 and 1013 attempts at Dyer Island from 2008 to 2019 (Table 2.2). The average fledging period at Stony Point was 75 days, while at Dyer Island it was significantly longer at 78 days (Two sample t-test: $t = -5.03$, $p < 0.001$). The longest fledging period at Stony Point was in 2015 at 78 days, and the shortest fledging period of 71 days was in 2019. The 78 days was significantly longer than the 71 days (Two sample t-test: $t = 4.90$, $p < 0.001$).

Table 2.2: Summary statistics of days to fledge for chicks at Stony Point (period 2013 to 2019) and Dyer Island (period 2008 to 2019).

Year	N	Mean	Median	SD
<u>Stony Point</u>				
All Years	1256	75	77	13.15
2013	209	73	71	11.21
2014	254	74	77	11.29
2015	157	78	77	15.30
2016	205	77	77	13.25
2017	133	76	73	13.51
2018	116	75	70	13.29
2019	182	71	70	13.40
<u>Dyer Island</u>				
All Years	1013	78	77	16.53
2008	158	79	77	15.65
2009	132	83	86	14.25
2010	144	82	82	15.65
2011	77	65	63	10.02
2012	170	78	74	10.29
2013	57	67	65	13.76
2014		No data available		
2015		No data available		
2016	40	86	91	15.99
2017	11	57	58	6.45
2018	56	79	78	23.74
2019	168	78	77	16.5

The fledging period at Dyer Island was significantly shorter in 2011 at 65 days than it was in 2016 at 91 days (Two sample t-test: $t = 1.24$, $p < 0.001$). Fledging periods shorter than 60 days are considered unusually short (Sheddon and van Heezik 1993). The results of 57 days from 2017 was therefore excluded, the sample size was also too small ($n=11$) to form a substantial conclusion. In 2011 the fledging period was 65 days and in 2013 it was 67 days; penguin chicks do not usually fledge until 75-80 days (Sheddon and van Heezik 1993). Large chicks can wander from their nests and evade detection which can lead to inaccurate data collection and may therefore indicate apparent short fledging periods (Sherley et al. 2013).

When comparing the days to fledge per month there was a trend for chicks to fledge in fewer days towards the end of the breeding season (Figure 2.1). At Stony Point eggs that were incubated in February took the longest to fledge (86 days, $n=21$). Eggs that were incubated in March at Dyer Island took the longest to fledge (83 days, $n=179$). There was, however, no significant difference between these two longest fledging months, February at Stony Point and March at Dyer Island (Two sample t-test: $t = 1.24$, $p = 0.220$). The shortest period to fledge at Stony Point was recorded for eggs incubated in August (61 days, $n=35$). The shortest period recorded at Dyer Island (June = 70 days, $n=33$) was significantly longer than Stony Point (Two sample t-test: $t = -2.76$, $p = 0.008$). Fledging periods shorter than 60 days are considered unusually short (Sheddon and van Heezik 1993; Sherley et al. 2012a) and were therefore excluded - July (58 days, $n=8$), the sample size was also too small to form a substantial conclusion.

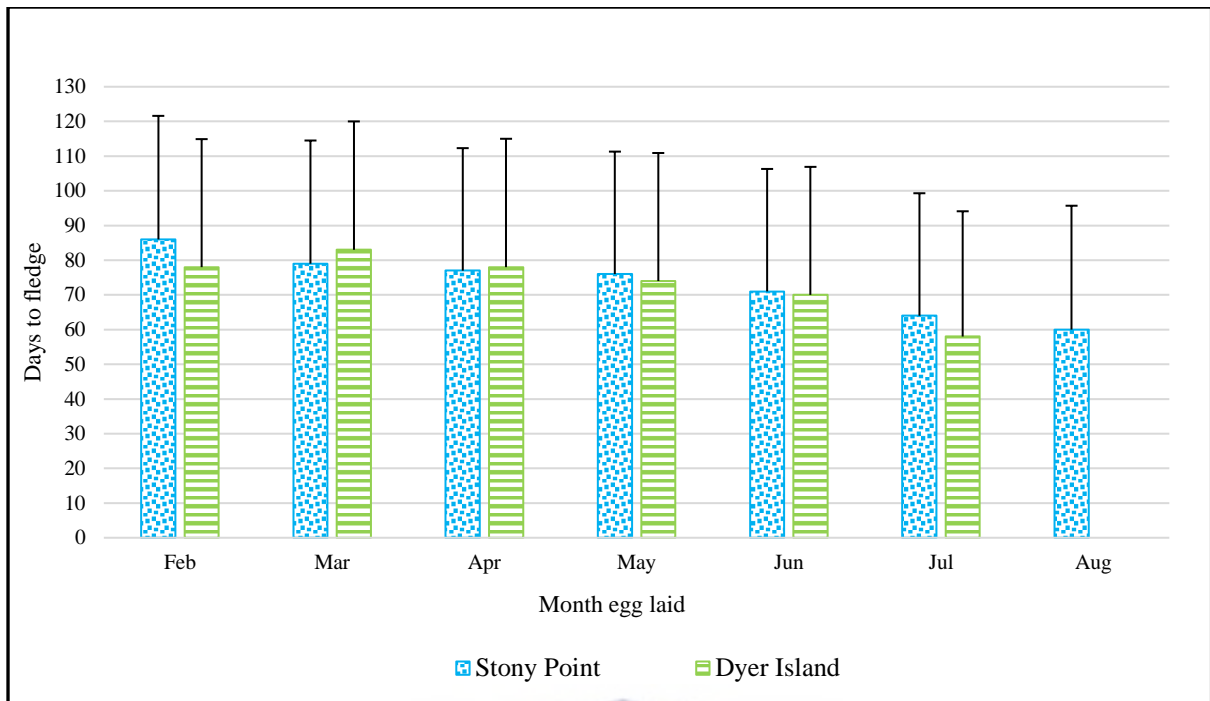


Figure 2.1: The mean number of days from February to August that chicks at Stony Point (period 2013 to 2019) and Dyer Island (period 2008 to 2019) took to fledge successfully. The number of days to fledge decreases towards the end of the breeding season. Bars represent SD.

2.3.3 Monthly breeding success comparison

The breeding season at Stony Point starts in February and ends in October, and at Dyer Island the breeding season starts in January and ends around September. On Dyer Island the Cape cormorants starts breeding in September and occupy the same nesting areas as the penguins. To limit disturbance during their nest building activities breeding success data collection can therefore only take place up until the cormorants start to occupy the island. The penguin breeding season at Dyer Island could therefore continue later in the year but currently there is no data available to verify this. The overall breeding success varies between months, but at both colonies the success rate is low in the beginning and end of the breeding season (Figure 2.2).

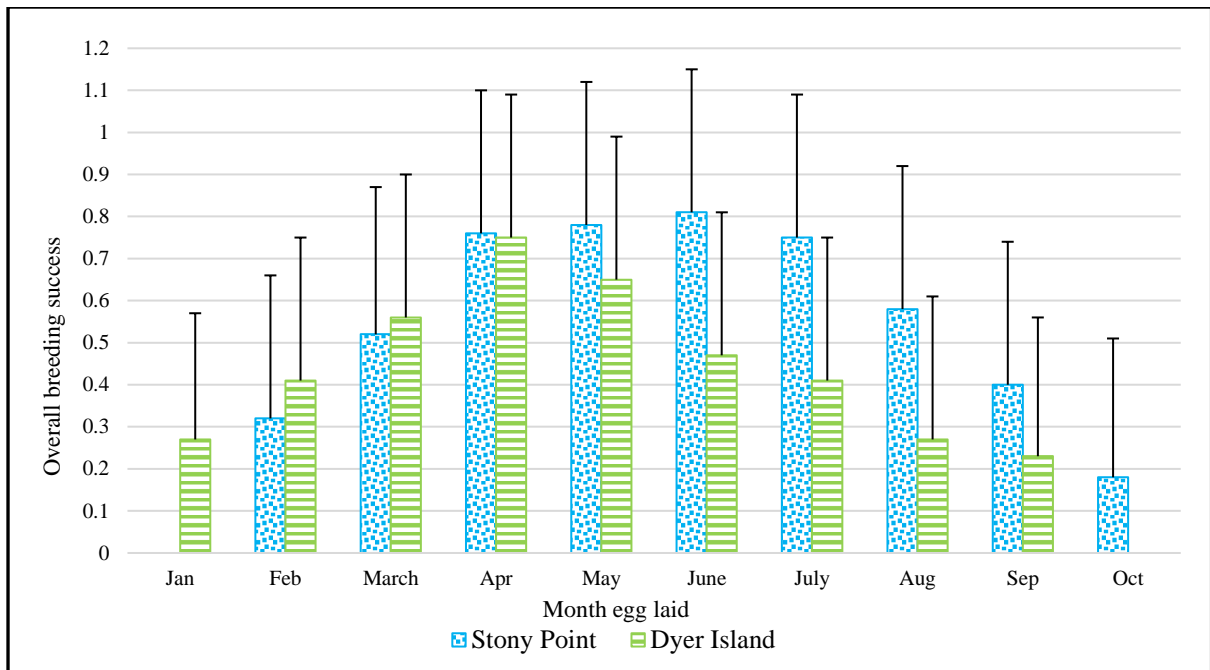


Figure 2.2: Mean overall breeding success for Stony Point (period 2013 to 2019) and Dyer Island (period 2008 to 2019) per month in which the eggs were laid. Both colonies show a decline in breeding success towards the end of the breeding season. Bars represent SD.

At Stony Point the peak of the overall breeding success took place in June (0.81, n=247) and was significantly higher than the April peak at Dyer Island at (0.75, n=827, Two sample t-test: $t = -2.68$, $p < 0.007$). The poorest overall breeding success was recorded in October at Stony Point (0.18, n=5) and in September at Dyer Island (0.23, n=3), but the sample size was too small to make a substantial conclusion. The second lowest rate was recorded in February at Stony Point (0.32, n=234); it was still significantly higher than the poorest rates recorded in January (0.27, n =125) and August (0.27, n=49) at Dyer Island (Kruskal-Wallis test: $H = 7.34$, $df = 2$, $p = 0.025$).

2.3.4 Breeding success comparison per nest type

The overall breeding success rate per nest type varied between 0.57 and 0.79 at both colonies (Figure 2.3). There was a significant difference between the nest types at Stony Point (Kruskal-Wallis test: $H = 18.45$, $df = 4$, $p < 0.001$), as well as a significant difference between the nest

types at Dyer Island (Kruskal-Wallis test: $H = 15.80$, $df = 3$, $p < 0.001$). The wooden box nest type (0.79) had a significantly higher overall breeding success rate than the natural burrows (0.59) at Stony Point (Two sample t-test: $t = 3.58$, $p < 0.001$). At Dyer Island the wooden box nest type had the highest overall breeding success rate (0.69) and the artificial burrows the lowest success rate (0.57). There was, however, no significant difference between the two types (Two sample t-test: $t = 1.86$, $p = 0.073$). The wooden box nest type sample size was small ($n=28$) which makes it difficult to form a substantial conclusion from the results gathered.

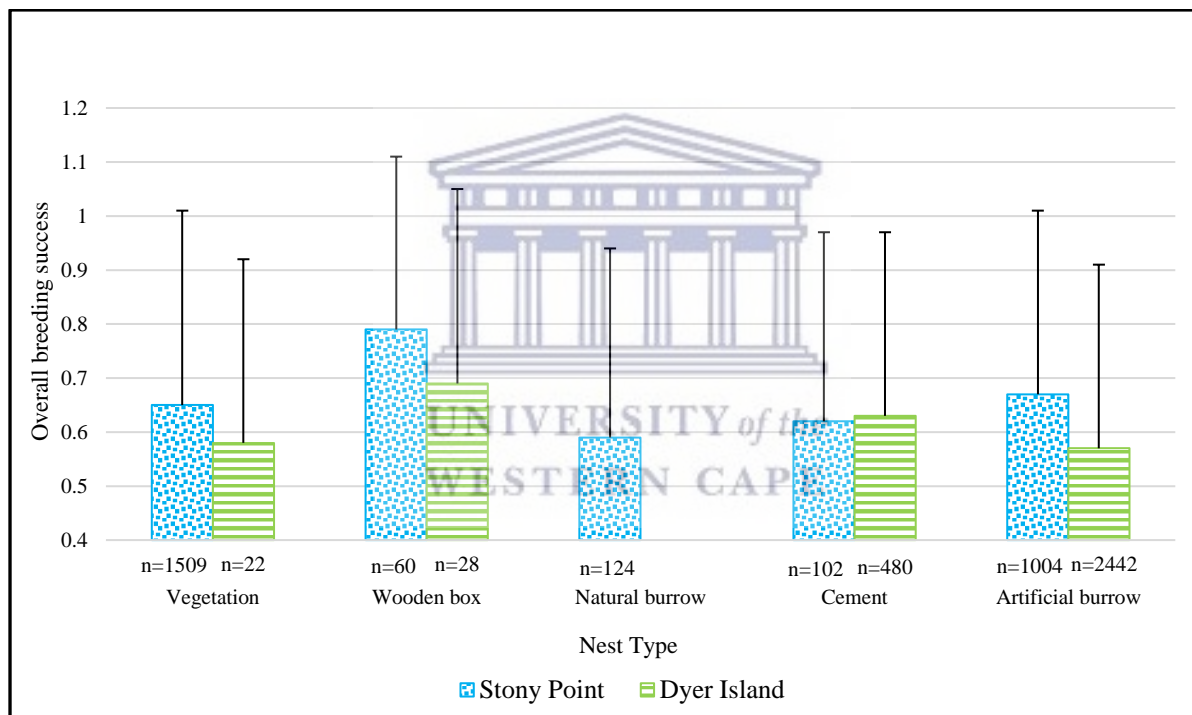


Figure 2.3: Overall breeding success per nest type for Stony Point (period 2013 to 2019) and Dyer Island (period 2008 – 2019). Bars represent SD.

2.4 Discussion

About 95% of seabirds are colonial breeders and during the breeding season they will become central place foragers to feed their chicks (Orians and Pearson 1979). They are sensitive to ecosystem changes and vulnerable to threats in and around their breeding colony that can

influence breeding success (Croxall 1992). In this study breeding success data collected at Stony Point for the period 2013 to 2019 and data from Dyer Island from 2008 to 2019, was used. The results indicated that there was no significant variation recorded in hatching success between the years and the two colonies. There was, however, a large variation in fledging success and overall breeding success between the years and the two colonies. These variations in results could be due to several factors which will be discussed below.

There can be competition with fisheries around some penguin breeding colonies, as fishing may reduce fish availability during high energy demands (Crawford et al. 2006a). During years when the numbers of fish available are low there can be increased competition between penguins and the pelagic fishery where foraging ranges and fishing areas overlap (Crawford et al. 2018). There may also be higher fishing intensity around Dyer Island than that of Stony Point and so African penguins at Dyer Island may face higher competition pressure. Breeding success can also be negatively affected by predators such as seals, kelp gulls and a few terrestrial predators (Seddon and van Heezik 1993). At Stony Point, data shows that the small grey mongoose predate on eggs and small chicks and the adults can be predated by seals, caracal and even leopard (Data provided by CapeNature, July 2020). Kelp gulls harass Cape cormorants (Voorbergen et al. 2012) and surface nesting penguins on Dyer Island (Data provided by CapeNature, July 2020) forcing them to expose their nest content which are then eaten. The culling of Kelp Gulls at Bird Island led to an increase in breeding success (Pichegru 2013). In 2015, 118 chicks died at Stony Point due to mongoose predation, this could have contributed to the reduction in overall breeding success of 0.58 (Data provided by CapeNature, July 2020). In 2016, 106 adult penguins were killed, and 123 were injured and removed at Stony Point. This was due to predation by Cape fur seal, leopard and caracal (Data provided by CapeNature, July 2020). This could have contributed to the low breeding success (0.58)

recorded for 2016 as only the remaining parent was left behind to feed the chicks. Weller et al. (2016) found that seal predation is the key driver behind the current decline in population numbers at Dyer Island. Predation could be a factor contributing to the variability in the breeding success at both Stony Point and Dyer Island.

African penguin chicks usually have full juvenile plumage between 61 and 65 days but can fledge anytime between 55 to 130 days (Seddon and van Heezik 1993). The results from this study indicated that the number of days chicks require to fledge the nest successfully varied between the years and the colonies. The days required to fledge did, however, show a decrease towards the end of the season at both colonies. At Stony Point the average fledging period, 75 days was shorter than the average period of 78 days at Dyer Island. The fledging period will vary according to food availability and the rate at which parents can provide food to chicks, e.g., longer fledging periods occurred when sardine biomass was low as shown during a study done at Robben Island (Sherley et al. 2013). Changes in the abundance of sardine and anchovy have been linked to diet and breeding success of various seabird species including the Cape Gannet, Cape Cormorant, swift terns and African penguin (Crawford et al. 2006a; Underhill et al. 2006). At Dassen Island it was also found that breeding success is significantly related to the available biomass of sardine and anchovy (Wolfaardt et al. 2008). At Robben Island the variation in growth of the population was strongly driven by the availability of food (Weller et al. 2016). During the breeding season penguins are range restricted, but outside the breeding season birds can travel further in search of food (Seddon and van Heezik 1991). Waller (2011) found that adult penguins predominantly forage in a c. 20 km radius from Dyer Island during the chick-rearing period. Food availability in this c. 20 km radius can therefore have an influence on breeding success and the number of days chicks require to fledge (Waller 2011).

According to the results of this study the breeding success varies between months at both Stony Point and Dyer Island, but at both colonies the success rate is low in the beginning and end of the breeding season. African penguins like other seabirds are endothermic and they can maintain their body temperature during colder temperatures. A slight increase in environmental temperature can, however, lead to heat stress and hyperthermia (Oswald and Arnold 2012). An adult is more likely to abandon the nest if it is consistently exposed to temperatures that require an increase in thermoregulation to tolerate the increase (Tol 2015). During periods of high temperatures, birds can leave the nest to cool down and rehydrate (Randal 1983). During this time, the nest content is vulnerable to predation; chicks can become heat stressed due to lack of shading and these factors can lead to breeding failure (Frost et al. 1976a). In 2016, 806 eggs were abandoned at Stony Point in February and March during the hatching phase, this can be the reason for the lowest hatching success (0.84) and overall breeding success (0.58) recorded for the period 2013 to 2019 (Data provided by CapeNature, July 2020). The abandonment of eggs has also been recorded at Dyer Island. At both Stony Point and Dyer Island the summer months of January to March are often marked by prolonged periods of high temperatures, this can contribute to the low breeding success at the beginning of the season.

The results suggested a decline in overall breeding success from July onwards in both colonies. The Western Cape is known for its high winds, heavy rainfall, and low temperatures during the winter months and these conditions can lead to the flooding of nests, collapse of natural burrows, drowning of chicks and death due to hypothermia (Frost et al. 1976a). Similar mortality was noted in the Arctic tern chick (*Sterna paradisaea*) and the Magellanic penguin (*Spheniscus magellanicus*) during heavy rains and cold temperatures (Boersma and Rebstock 2014). Young chicks that are not yet thermally independent as well as larger chicks that do not have their waterproof plumage, will not be able to maintain their body temperature and are

therefore susceptible to hypothermia (Boersma and Rebstock 2014). At Stony Point 129 chicks died in 2013 due to hypothermia and flooding, the average rainfall in 2013 was 1500 mm compared to the average of 900 mm of the other years (Data provide by Harold Porter Botanical Garden, June 2021). This could be the reason for the lowest fledging success result of 0.71 calculated in 2013 for the period 2013 to 2019.

Adult African penguins will leave the nest for the annual moulting season at the end of the breeding season. At both Stony Point and Dyer Island chicks that have not yet fledged in the nest, will be left unattended and unfed during the months of September and October (Data provided by CapeNature, July 2020). This has led to the removal of poor condition chicks to rehabilitation centres towards the end of the season to increase their body condition before they can be released again. Chicks that were removed from the nest were not included in the breeding success analysis in this study. It is not always possible to find and remove all the poor condition chicks that are no longer fed by parents. These chicks can die from starvation, and this can contribute to the lower breeding success at the end of the season at both colonies.

It is vital for seabirds to have a nesting habitat that ensures protection from environmental conditions. African penguins historically nested in burrows dug in guano or other soft substrates, that provided protection against predators and diurnal temperature fluctuations (Frost et al. 1976a). Due to the removal of guano, penguins now nest on the surface or in artificial nest types. High temperatures and rainfall can cause failure of penguin's nests, but the survival probabilities can vary according to the nest type (Sherley et al. 2012a; Boersma and Rebstock 2014). The results from this study indicated that the wooden box nest type had the highest overall breeding success at both Stony Point (0.79) and Dyer Island (0.69). During studies done at Robben Island it was also found that wooden box nest types had the highest

success rate (Tol 2015; Barham 2017). Tol (2015) found that surface nests covered by vegetation experienced cooler temperatures on hot days compared to artificial nests, yet at Stony Point the artificial burrows (0.67) had a higher success rate compared to the vegetation nests (0.65). This suggests that other factors such as predation, parasites, rain and flooding may be involved. The cement nests (0.62) and natural burrows (0.59) had the lowest success rate at Stony Point. Due to the sandy soil substrate natural burrows often collapsed at Stony Point with the nest content still inside, which may have contributed to the low breeding success rate of natural burrows (Data provided by CapeNature, July 2020).

At Dyer Island the artificial burrows (0.57) surprisingly had the lowest success rate of all the nest types on the island. Sherley et al. (2012a) found that artificial nests provided more protection against weather conditions than surface nests that had no cover. Surface nests, even if covered with vegetation are exposed to high ambient temperatures, solar radiation and flooding (Randall 1983). When adults must leave surface nests, the contents are vulnerable to predation (Seddon and van Heezik 1991). Artificial nests have been placed at both Stony Point and Dyer Island to improve the nesting habitat and provide protection. Tol (2015) found that artificial nests can be used as substitute nesting habitat but some of the current designs are not optimal because they attract more heat than natural nest types. Higher soil temperatures were recorded in artificial nests compared to open surface nests and nests covered with vegetation (Espinaze et al. 2020). Artificial nests can act as ecological traps if the nests do not replicate the natural nesting conditions (Sutherland et al. 2014). Some artificial nest designs for African penguins can produce microclimates that are not conducive to breeding (Lei et al. 2014). The placement of artificial nests is also important; lower average temperatures have been recorded in artificial nest boxes facing west compared to those facing east or south (Butler et al. 2009). In a recent study at Stony Point, it was also found that nest characteristics impact on the

microclimatic conditions of penguin nests. Artificial nests at Stony Point had a higher nest parasite infestation compared to other nest types sampled, which can affect the health and breeding success of African penguins (Espinaze et al. 2019).

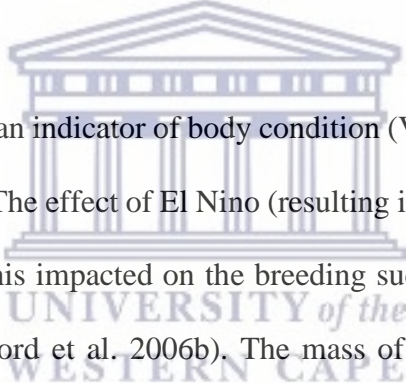
2.5 Conclusion

The results of this study indicated no significant difference between the colonies and years when comparing the hatching success. There was, however, a large variability between years and the two colonies for both fledging success and overall breeding success. The mean fledging success and overall breeding success were significantly higher at Stony Point than Dyer Island. The number of days chicks required to fledge the nest (fledging period) showed a variation between the years and the colonies. The average fledging period was shorter at Stony Point compared to Dyer Island. Surprisingly the days chicks required to fledge from the nests decreased towards the end of the breeding season at both colonies. The overall breeding success showed a variation between the months, but at both colonies the success rate was low at the start and end of the breeding season. Stony Point and Dyer Island colonies are geographically in close proximity and thus one would expect similar breeding success results. It would be useful to develop a deeper understanding of the population dynamics and factors that can influence them to assist in understanding the variation in breeding success between the two colonies. The overall breeding success varied between nest types, with the wooden box nest type the most successful type. The variability of breeding success between nest types indicated that nest types can affect breeding success. The design and placement of artificial nests at colonies should therefore be further investigated.

CHAPTER 3 – CHICK CONDITION

3.1 Introduction

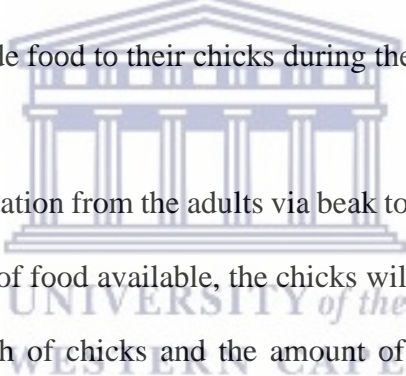
The behaviour and reproduction of seabirds have been used as indicators of marine resources or local food availability (Robinson et al. 2005; Boersma 2008). The African penguin, as a marine top predator, can provide insight into ecosystem changes and regional ocean productivity (Boersma 2008). Robinson et al. (2005) found that the breeding biology of the Little penguin is intricately linked with available marine resources. Body condition has been established as a reliable indicator of food supply (Monaghan et al. 1994).



Many studies use body mass as an indicator of body condition (Vleck and Vleck 2002; Ballard et al. 2010; Salton et al. 2015). The effect of El Nino (resulting in warmer nutrient-poor water) reduced food availability and this impacted on the breeding success of Humbolt penguins in Peru in 1982 and 1983 (Crawford et al. 2006b). The mass of Macaroni penguin (*Eudyptes chrysolophus*) chicks at Marion Island was related to the number of fish in their diet (Crawford et al. 2003). The body condition of a seabird can influence the decision to allocate food to its offspring or to build up its own energy reserves for survival (Weimerskirch et al. 1997). Breeding Antarctic petrels (*Thalassoica antarctica*) with low body mass would be more likely to prioritize their own energy requirements before that of their chicks (Varpe et al. 2004).

The body condition of an animal refers to the proportion of its body mass which is available to the animal in the form of metabolizable energy reserves (Lubbe et al. 2014). Body condition indices have been generated to serve as an estimate of the organism nutritional state and general health (Jakob et al. 1996). Body condition has been used in various studies focussing on the

reproductive success, foraging success and survival within variable environmental conditions (Warner et al. 2016). Body condition is a useful tool in the management of wildlife and conservation (Labocha and Hayes 2012). The indices contribute valuable information on the health of the individuals and the population (Mallory et al. 2010). Animals with a poor condition can be removed from the wild and send to rehabilitation centres to improve their body condition before they can be released again. Chick condition can be used as an index to assess the local feeding conditions at a given colony. It can also be used to compare feeding conditions between colonies and years. (Lubbe et al. 2014). Once eggs have hatched, food caught at sea must be brought back to the chicks at the colony. The chicks of African penguins are altricial and dependant on their parents for food provision. Adult penguins must return regularly to the colony to provide food to their chicks during the breeding season.



Chicks are fed by direct regurgitation from the adults via beak to beak (Seedon and van Heezik 1991). If there is an abundance of food available, the chicks will grow well as there is a direct relationship between the growth of chicks and the amount of food they receive from their parents (Campbell 2016). Food availability must be adequate to ensure good body condition and successful breeding (Clarke 2001; Campbell et al. 2019). Chick condition can therefore be used as an indicator of the feeding conditions around the breeding colony (Lubbe et al. 2014).

The aim of this chapter was to evaluate differences in chick condition index for the African penguin at Stony Point and Dyer Island. The variabilities between breeding years, months and colonies were also explored. The study also aimed to determine if chick condition varied between nest types.

3.2 Methodology

3.2.1 Data collection

During the penguin breeding season staff from CapeNature collected a sample of chick body measurements (head length and weight) as part of the annual chick condition-monitoring programme. At Stony Point chick body measurements were analysed for the period 2013 to 2019 and at Dyer Island measurements from 2008 to 2019 were analysed. A minimum of 30 chicks were measured once a month during the breeding season. The nest content was also recorded at each nest – singleton (only one chick), A-chick and B-chick in the case of two chicks present at the nest. Chicks were not marked during the measurements (to limit disturbance), but it was assumed that the smaller chick in the nest was the B-chick. At both colonies, the nest type were recorded along with the head length and mass of each chick in the nest. The total head length, which was taken from the tip of the culmen to the base of the skull, was measured with vernier callipers to the nearest 0.1mm. The body mass of chicks was measured to the nearest 10g using electronic handheld balances and a harness or bag to hold the chicks. Chicks were classed according to their age between P0 to P4.

3.2.2 Data analyses

Chicks with a total head length of <75mm were not measured and are not included in the condition analysis. According to Lubbe et al. (2014) the period of linear growth between mass and head length corresponds with chicks older than 20 days, but in chicks younger than 20 days the growth is slow and therefore the difference in body condition at that early stage is considered insignificant. Lubbe et al. (2014) used quantile regression techniques to modify the condition index developed by Veen et al. (2004). A dataset collected at Robben Island in 2004 was used to examine the structural growth in relation to age and mass, including growth relative

to each other (Bouwhuis et al. 2007). For a chick with a particular total head length the condition of the chick is defined as the proportion of the distance between the upper and lower quantiles.

Lubbe modified BC14 Veen index is defined as follows:

Body Condition = (Observed mass – Predicted 5% minimum mass).

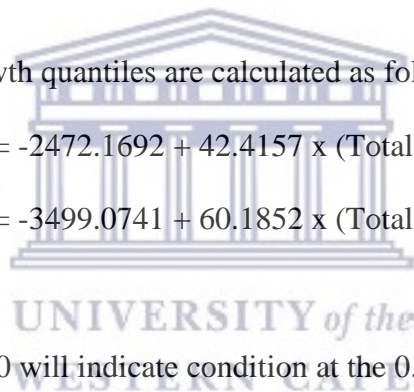
(Predicted 95% maximum mass – Predicted minimum 5% mass).

The lower and upper growth lines are represented by the 5% and 95% quantile lines. In the index the predicted 5% and 95% mass for an African penguin chick with a given total head length was derived from the 0.05 and 0.95 quantile regression lines.

The minimal and maximal growth quantiles are calculated as follows:

0.05 quantile: mass (in grams) = $-2472.1692 + 42.4157 \times$ (Total head length in mm).

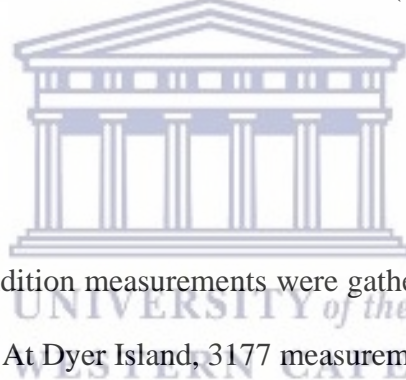
0.95 quantile: mass (in grams) = $-3499.0741 + 60.1852 \times$ (Total head length in mm).



A condition value of 1.0 and 0.0 will indicate condition at the 0.95 quantile and 0.05 quantile. Data points above the 0.95 quantile will indicate chicks with a body condition index greater than one and data points below 0.05 will indicate chicks with a negative body condition index (Lubbe et al. 2014). Body condition index values that exceed 1.0 and values below 0.0 are also valid. The condition of chicks can therefore be described as the proportion between the upper and lower quantiles for a given total head length of a chick (Lubbe et al. 2014). The condition index was developed using data from Robben Island in 2004 where a value of 0.5 is representative of the average body condition of African penguin chicks on Robben Island that fledged successfully in 2004 (Bouwhuis et al. 2007).

During the study, the mean chick condition for each year was calculated and compared between each year and between the two colonies. The mean chick condition for each month for each colony was also calculated, along with the mean chick condition per nest type. In nearly all cases the data were not normally distributed so that parametric statistical tests were not appropriate and accordingly, only non-parametric tests were used throughout. For simplicity and ease of comparison, the Kruskal-Wallis H-test was used for all tests of independent samples (even when there were only two groups as it gives similar results to the possibly more appropriate Mann Whitney U-test). A significance level of 5% was used in all tests. For the Kruskal-Wallis tests the values of: H (chi-squared), df (degrees of freedom) and p was provided. Data were expressed as means \pm standard deviation (SD).

3.3 Results



At Stony Point, 1607 chick condition measurements were gathered for the analyses for the 7-year period from 2013 to 2019. At Dyer Island, 3177 measurements were collected for the 11-year period from 2008 to 2019. The data were collected between May and November at Stony Point and March to November at Dyer Island which is the breeding season period when most chicks are present in the colonies (Crawford et al. 1999).

3.3.1 Yearly chick condition comparison

The number of measurements taken annually at Stony Point between 2013 and 2019, ranged from 127 to 410 with a mean of 230 for the 7-year period (Table 3.1). At Dyer Island the number ranged from 28 to 978 with a mean of 318 for the 11-year period between 2008 and 2019 (Table 3.1). There were no data available for chick condition for 2014 and 2015. The

mean chick condition in the two colonies was characterized by a large variation between each year and between the two colonies.

Table 3.1: Summary statistics of chick condition for Stony Point (period 2013 to 2019) and Dyer Island (period 2008 to 2019).

Year	n	Mean	Median	SD	Min	Max
<u>Stony Point</u>						
2013	410	0.25	0.27	0.39	-0.88	1.78
2014	237	0.34	0.38	0.39	-0.98	1.19
2015	187	0.46	0.51	0.32	-0.95	1.13
2016	127	0.53	0.53	0.27	-0.19	1.60
2017	315	0.30	0.27	0.69	-1.15	3.80
2018	197	0.32	0.37	0.50	-1.21	3.29
2019	134	0.61	0.64	0.44	-0.65	2.15
<u>Dyer Island</u>						
2008	978	0.27	0.25	0.39	-1.37	2.07
2009	882	0.18	0.23	0.47	-1.19	1.48
2010	313	0.26	0.21	0.50	-1.75	3.72
2011	368	0.18	0.23	0.47	-2.07	3.49
2012	298	0.27	0.17	0.84	-1.31	3.22
2013	44	0.18	0.15	0.23	-0.22	0.72
2014		No data available				
2015		No data available				
2016	40	0.41	0.38	0.39	-0.27	1.76
2017	109	0.32	0.36	0.39	-1.48	1.34
2018	28	0.33	0.38	0.39	-0.79	0.93
2019	117	0.29	0.33	0.38	-1.27	0.98

The mean chick condition index at Stony Point (0.36) for the period 2013 to 2019 was higher than the mean at Dyer Island (0.23) for the period 2008 to 2019. The body condition of chicks at Stony Point were significantly better than those at Dyer Island (Kruskal-Wallis test: $H = 113.60$, $df = 1$, $p < 0.001$). The mean chick condition at both Stony Point (0.36) and Dyer Island (0.23) was, however, lower than the baseline data set of Robben Island (0.51) used to develop the condition index (Bouwhuis et al. 2007). Only the year 2016 and 2019 at Stony Point was higher than Robben Island with an average of 0.61. The highest mean chick condition 0.61

(range -0.65 to 2.15, n=134) was recorded during 2019 at Stony Point and 2013 measured the lowest mean chick condition at 0.25 (range -0.88 to 1.78, n= 410). There was a significant difference between the year 2013 and 2019 (Kruskal-Wallis test: $H = 70.69$, $df = 1$, $p < 0.001$). At Dyer Island the highest mean chick condition 0.41 (range -0.27 to 1.76, n=40) was measured in 2016. The years 2009, 2011 and 2013 had the lowest mean chick condition at 0.18 and showed a significant difference between the years (Kruskal-Wallis test: $H = 13.45$, $df = 3$, $p = 0.003$).

3.3.2 Monthly chick condition comparison

There was a difference in the seasonal pattern of mean monthly chick condition between Stony Point and Dyer Island (Figure 3.1). The mean monthly chick condition at Stony Point ranged from 0.28 to 0.41 (SD ranged from 0.39 to 0.44) and is consistently higher (except for the month of May) compared to Dyer Island with a range from 0.02 to 0.40 (SD ranged from 0.19 to 0.36). There was a significant difference between the monthly chick condition (Kruskal-Wallis test: $H = 14.90$, $df = 5$, $p = 0.010$) at Stony Point as well as at Dyer Island (Kruskal-Wallis test: $H = 196.45$, $df = 7$, $p < 0.001$).

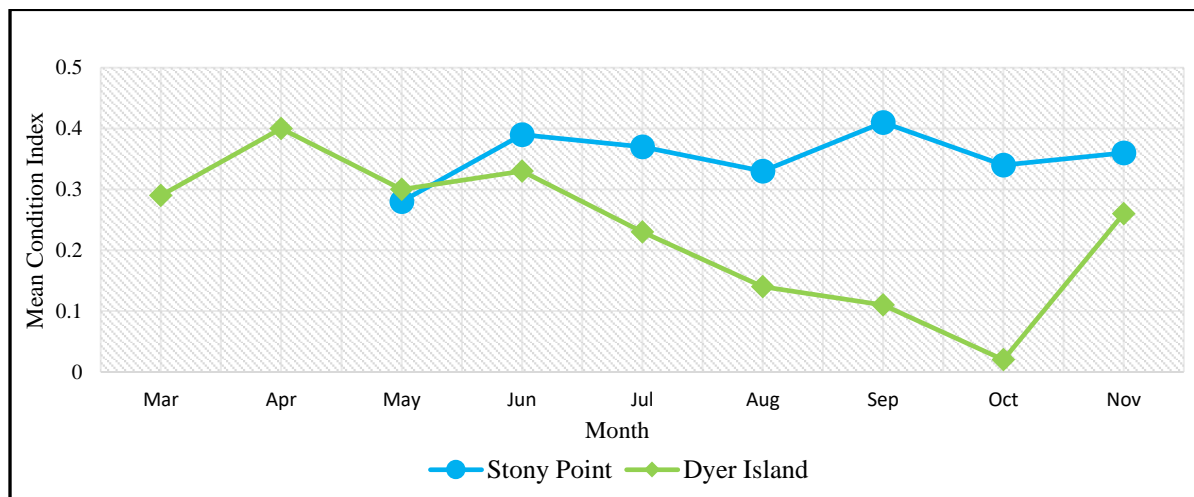


Figure 3.1: The mean monthly chick condition for Stony Point (period 2013 to 2019) and Dyer Island (period 2008 to 2019) during the breeding season.

At Stony Point, September was the month with the highest mean chick condition at 0.41 (range = -1.10 to 2.15, n=245). The month with the lowest mean chick condition was May -0.28 (range = -0.98 to 3.29, n=112). There was a significant difference between the two months (Kruskal-Wallis test: $H = 11.36$, $df = 1$, $p < 0.001$). There was no decline in mean chick condition during the breeding season at Stony Point. The mean monthly chick condition at Dyer Island showed a decline towards the end of the breeding season except for the month of November. The highest mean monthly chick condition was recorded in April 0.40 (range = -0.75 to 2.07, n=148). The lowest mean monthly chick condition at Dyer Island was recorded in October at 0.02 (range = -0.95 to 0.87, n=151). There was a significant difference between the two months (Kruskal-Wallis test: $H = 80.85$, $df = 1$, $p < 0.001$). There was no significant difference between September, the highest month at Stony Point and April, the highest month at Dyer Island (Kruskal-Wallis test: $H = 0.47$, $df = 1$, $p = 0.48$). There was a significant difference between May, the lowest month at Stony Point and October, the lowest month at Dyer Island (Kruskal-Wallis test: $H = 27.83$, $df = 1$, $p < 0.001$). The seasonal differences and difference between the two colonies will be explained in the Discussion section.

3.3.3 Comparison of chick condition per nest type

Chick condition can be affected by climatic conditions as chicks are exposed to an increase or decrease in temperature leading to a depletion of energy reserves. Chicks can be exposed to changes in climatic conditions according to the type of nests they occupy. The relationship between nest type and chick body condition was therefore investigated. The number of measurements available per nest type analysis were reduced because the field staff did not always record the nest type during chick condition measurements. Out of the 1607 chick condition measurements collected at Stony Point from 2013 to 2019, the nest type was not

recorded for 373 measurements. At Dyer Island the nest type of 416 measurements out of the total of 3177 was not recorded by field staff during the period of 2008 to 2019.

The wooden box nest type at Stony Point showed the highest mean chick condition measured at 0.62 (range -0.82 to 1.75, n=30), (Figure 3.2). The cement nest type had the second highest mean chick condition at 0.54 (range -0.45 to 3.80, n=14) and the natural burrows had the lowest mean chick condition at Stony Point 0.19 (range -0.95 to 1.95, n=90). There was a significant difference between the five nest types at Stony Point (Kruskal-Wallis test: $H = 41.74$, $df = 4$, $p < 0.001$). There was only a 0.02 difference in mean chick condition between the two largest samples sizes, vegetation nests 0.36 (range -1.15 to 2.95, n=548) and artificial burrows 0.38 (range -1.09 to 3.23, n=553). There was a significant difference between the vegetation nests and the artificial burrows ($p < 0.001$).

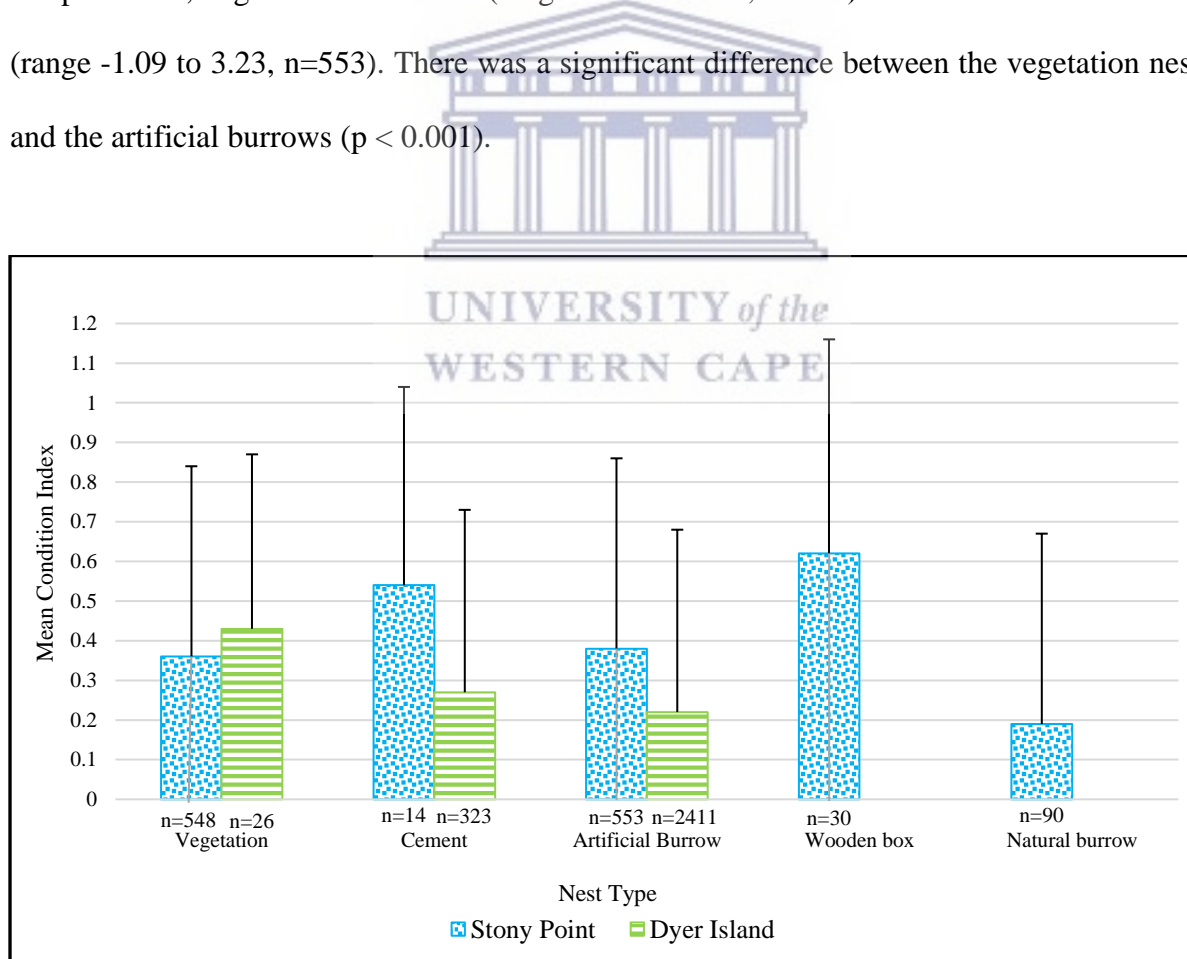


Figure 3.2: Mean chick condition per nest type for Stony Point (period 2013 to 2019) and Dyer Island (period 2008 to 2019). Bars represent SD.

At Dyer Island the vegetation nests had the highest mean chick condition at 0.43 (range -0.29 to 0.94, n=26). Cement nests had the second highest mean chick condition at 0.27 (range -1.48 to 1.37, n=323) and the artificial burrows had the lowest mean chick condition 0.22 (range -2.37 to 3.72, n=2411). There was a significant difference between the 3 nest types at Dyer Island (Kruskal-Wallis test: $H = 14.38$, $df = 3$, $p < 0.001$). Although 80% of Dyer Island nests are exposed surface nests with no cover, the measurements of chicks at these nests were limited to reduce disturbance (Ludynia et al. 2014). Guano harvesting on Dyer Island reduced the burrowing substrate resulting in an exceptionally low number of natural burrows currently on the island (Ludynia et al. 2014). There are only 30 wooden boxes available on Dyer Island for breeding, these were either not included in the measurements or the nest type not recorded by field staff. There was a significant difference between artificial burrows and cement nests ($p = 0.02$); between artificial burrows and vegetation nests $p < 0.001$ as well as between cement nest and vegetation nests ($p = 0.009$). When comparing the nest types between the colonies it was found that there was a significant difference in chick condition for artificial burrows at Stony Point and Dyer Island (Kruskal-Wallis test: $H = 76.21$, $df = 1$, $p < 0.001$). There was no significant difference in chick condition for cement nests between Stony Point and Dyer Island (Kruskal-Wallis test: $H = 0.74$, $df = 1$, $p = 0.388$) and for vegetation nests between Stony Point and Dyer Island (Kruskal-Wallis test: $H = 1.24$, $df = 1$, $p = 0.263$).

3.3.4 Relationship between chick condition and breeding success

The overall breeding success data per month (month egg laid) were compared to the mean chick condition per month (month chick measured) during the period 2013 to 2019 from May to October for Stony Point and 2008 – 2019 from March to September for Dyer Island. The chick condition index at Stony Point is constant with a slight difference between the months (Figure 3.3A). There was a decrease in breeding success from August to October. But it seems

there was no correlation between chick condition and breeding success (Pearson correlation coefficient, $R^2 = -0.14$). At Dyer Island the condition index of the penguin chicks showed a decline from June through to September (Figure 3.3B). The overall breeding success of the Dyer Island colony also decreased from May to October. There was a correlation found between chick condition and overall breeding success at Dyer Island (Pearson correlation coefficient, $R^2 = 0.93$).

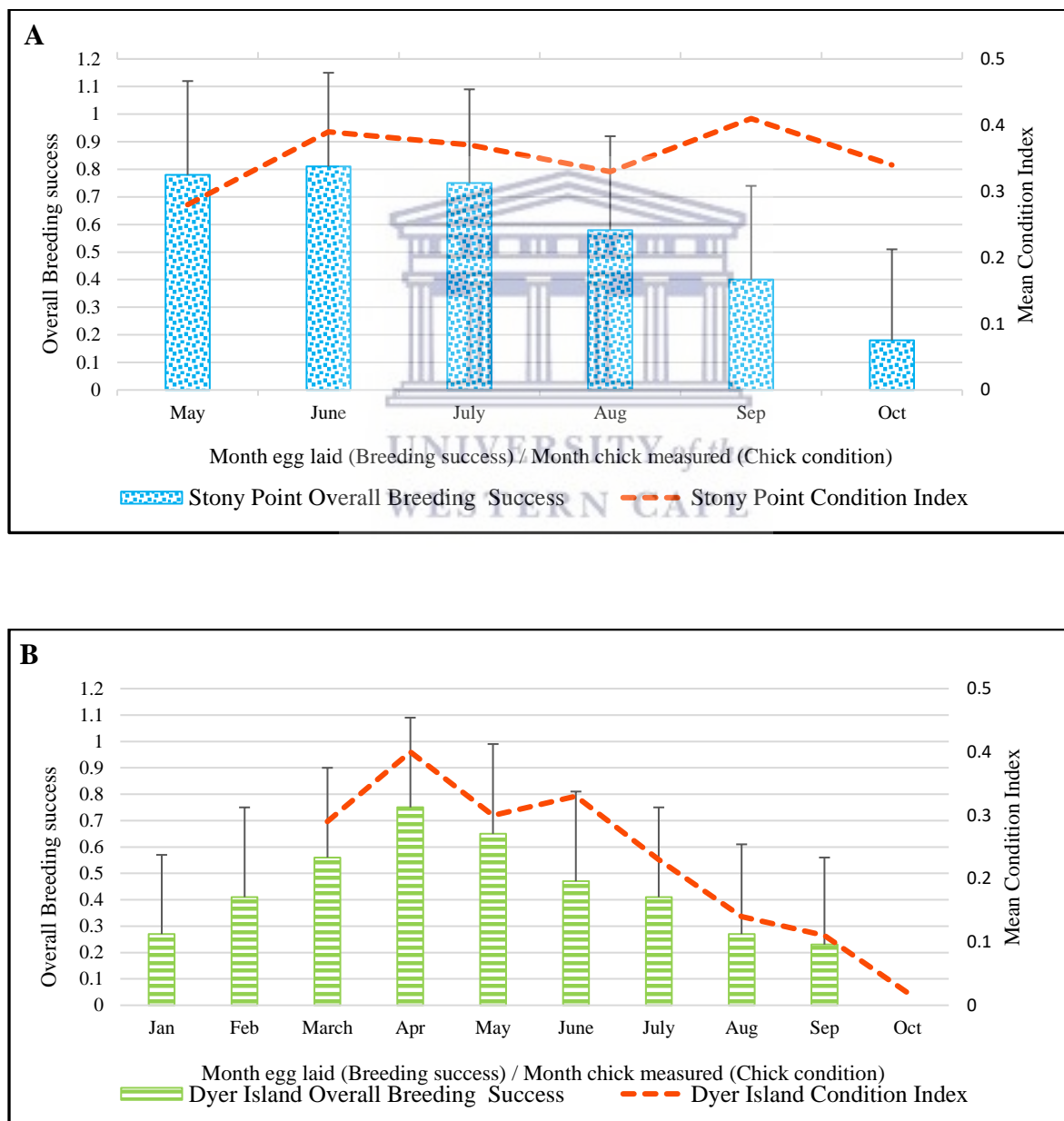


Figure 3.3: Monthly overall breeding success (month egg laid) and chick condition at Stony Point (A) and Dyer Island (B). Bars represent SD.

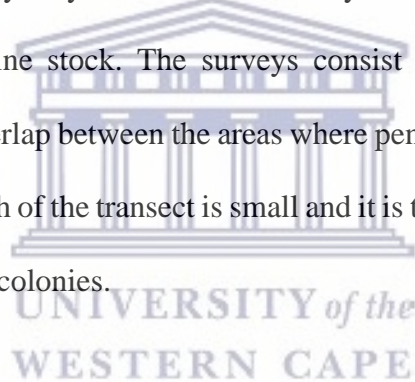
3.4 Discussion

Lubbe's condition index were applied to a large dataset from Stony Point and Dyer Island in this study (Lubbe et al. 2014). The results showed a large variation in chick condition between years and between the two colonies. The Stony Point chicks (mean of 0.36) were in an overall better condition than those of Dyer Island (mean of 0.23). But at both colonies the mean condition was still lower than the mean condition 0.51 of the 2004 Robben Island baseline data set (Lubbe et al. 2014). The body condition of chicks has been related to the availability of prey (Waller 2011; Lubbe et al. 2014) with African penguins requiring adequate food supplies in close proximity to the colonies during breeding season (Sherley et al. 2013).

African penguins feed primarily on anchovy and sardine (Crawford et al. 2013). Two factors that can influence their access to sufficient prey include direct competition with commercial fisheries that target the same fish resources as well as the overall biomass (Sherley et al. 2013). The regional abundance of sardine and anchovy have been linked to the breeding success and fledging rates of African penguins (Crawford et al. 2006a; Sherley et al. 2013). During times of food shortages, it is predicted that penguin parents will provide less food than is needed to maintain chick survival (Sherley et al. 2013). The poor diet due to food shortages can influence African penguin growth rates and cause starvation (Seddon and van Heezik 1993). Therefore during times of food shortages the condition of chicks will deteriorate.

The decline in chick condition at both colonies relative to that observed at Robben Island in 2004 could be due to a deterioration in fish availability for penguins at both colonies during the breeding season. Campbell (2016) found a direct relationship at Robben Island between chick body condition and local prey abundance and composition. African penguins are central

place foragers and most penguins feed within c. 20 km of their breeding colonies (Petersen et al. 2006; Pichegru et al. 2010). The breeding success and condition of the Adélie penguins (*Pygoscelis adeliae*) at Bechervaise Island decreased when the adults had to forage further from the colony and returned with fewer or smaller meals for the chicks (Ballard et al. 2010). Their foraging range is constrained by having to return to the nests to feed chicks. Boersma and Rebstock (2009) found that more chicks were reared in colonies where the penguins could feed close to the colony compared to those colonies where penguins had to feed further from their colony. The variation in chick condition between the years at both Stony Point and Dyer Island could be due to a reduction of food resources. The Department of Forestry, Fisheries and Environment (DFFE) conduct yearly fish biomass surveys to estimate the distribution and biomass of anchovy and sardine stock. The surveys consist of parallel transects (method described in Chapter 4); the overlap between the areas where penguins at Stony Point and Dyer Island forage and the total length of the transect is small and it is therefore difficult to determine the food availability at the two colonies.



Predation has been identified as a potential population driver for African penguins (DEA 2013). At Dyer Island the adults are exposed to the threat of seal and shark predation and the chicks can be predated by kelp gulls. An estimated number of between 7 - 8% of the breeding numbers of the island are annually predated by seals (Ludynia et al. 2014). If one parent is predated the remaining parent is left behind to feed the chicks, this can impact the amount of food that a chick receives which in turn can impact the condition of the chick. At Stony Point, a land-based colony, the penguin chicks are exposed to terrestrial predators such as feral cats and dogs, small and large grey mongoose and caracal (Data provided by CapeNature, July 2020). The adult penguins can be predated by caracal, seals and even leopard. In 2016 a caracal and leopard predated 52 breeding penguins at Stony Point, resulting in only one parent being able to feed

the chicks (Data provided by CapeNature, July 2020). Predation could also have an impact on chick condition and causes variation between the years and two colonies.

The results from this study suggested a difference in the seasonal pattern of mean monthly chick condition between Stony Point and Dyer Island. There was substantial variability between the months at both colonies and the peak chick condition occurred in different months; at Stony Point it was in September and at Dyer Island in April. The peak in chick condition recorded in April at Dyer Island in this study corresponds to what Waller (2011) found at other colonies - where Dassen Island peaked in April 2009 and Robben Island peaked in May 2004. It is unclear why Stony Point peak condition is so late in the breeding season (September). It could be due to climatic and/or oceanographic conditions; this requires further research.

The variability in the chick condition between months and colonies can be due to variable feeding conditions and unpredictable environment (Waller 2011). Kemper (2006) found that breeding is less synchronous in an unpredictable environment and can lead to an extended breeding season. Prey species which are normally consumed by African penguins, migrate to the east coast during the warmer months of the year and only return in the winter period (Crawford 1998). Towards the end of the breeding season adult penguins must leave the colony for a four-week period to build up sufficient fat reserves to be able to survive the starvation period on land during the moulting season. Any chicks that have not fledged during this time can be left unattended and unfed (Sherley et al. 2014a). This can contribute to the drop in body condition towards the end of the breeding season observed at Dyer Island.

July and August are the peak winter months in the Western Cape, during this time chicks are exposed to exceptionally low temperatures, heavy rainfall, flooding and wind. Chicks on Dyer

Island are exposed to storms and wind up to 90 km/h (CapeNature 2012). This can lead to a drop in body condition due to a depletion of energy reserves to try to maintain body temperature as penguin chicks are not able to compensate for heat loss (Erasmus and Smith 1974). Exposure and nest flooding can cause African penguin chick mortality (Seddon and van Heezik 1991). The average number of chicks that die at Stony Point during the cold winter months due to flooding and hypothermia is 20 and an average of 30 are removed in July and August because of their overall poor condition (Data provided by CapeNature, July 2020).

Wooden nest boxes were the most successful nest type at Stony Point with an average chick condition of 0.62. But it is difficult to make a substantial conclusion about this because it is a small data set (n=30); the wooden nest boxes were only placed at Stony Point in 2017 (Data provided by CapeNature, July 2020). At both colonies artificial burrows show a low mean chick condition. Catry et al. (2011) found an increase in chick mortality and poorer body condition in lesser kestrels (*Falco naumanni*) inside nest boxes. The chick condition was adversely affected by the temperature inside the nests. An increase in temperature might accelerate the metabolic rate of chicks, resulting in a depletion of energy reserves which reflects in their body condition. Recent studies on various artificial nest types have shown contrasting success between localities and artificial nest types (Sherley et al. 2012a, Pichegru 2013).

In a study conducted at Stony Point and Dyer Island, penguin chick condition declined when the nest soil temperature increased and the soil temperature in artificial nests was higher compared to other nest types (Espinaze et al. 2020). Chicks nesting in cement nests may be in better condition at both colonies due the fact that the ambient nest temperature and humidity is lower in cement nests compared to artificial burrows (Lei et al. 2014). Chicks at Stony Point exhibited lower chick condition in vegetation nests compared to chicks at Dyer Island. The

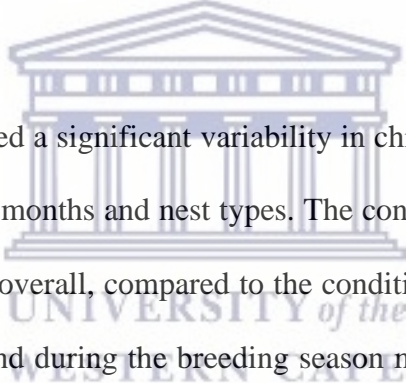
decline in chick condition can be related to the fact that chicks in vegetation nests are more exposed to climatic conditions such as wind, rainfall, heat and sunlight (Kemper et al. 2007b). Chicks in vegetation nests and surface nests without cover are more exposed to extreme variations in temperature as well as heavy rainfall and flooding (Pichegru 2013). Surprisingly, the chick condition for vegetation nests at Dyer Island had the highest mean compared to the other nest types. But the sample size was small (n=26) to limit disturbance to chicks and this made it difficult to form a substantial conclusion. Natural burrows had the lowest mean chick condition at Stony Point, it is difficult to determine the reason for this, but might be due to the increase in temperature of the sandy soil substrate.

The Stony Point data showed no correlation between overall breeding success and chick condition, whereas at Dyer Island there was an obvious correlation ($R^2=0.93$). Body condition has been linked to breeding success in seabirds in several studies. In blue petrels (*Halobaena caerulea*) the early body condition of adults has influenced their decision to breed (Chastel et al. 1995). If the body condition of the adults is poor at the start of the breeding season it could result in abandonment of nests during incubation (Chastel et al. 1995). If the parents can build up energy reserves before the onset of the breeding season, they may be able to maintain their own reserves while providing food for their chicks (Robinson et al. 2005). Thus, body condition at the onset of the breeding season may determine reproduction success and the amount of parental investment into breeding preparations may improve the survival of their offspring (Salton et al. 2015).

Breeding parents will be better able to balance the trade-off between self-maintenance and chick provision if energy reserves are combined with abundant local prey availability (Sherley et al. 2013). This can then result in improved breeding success and chick condition as the adults

are able to provide more resources to their growing chicks (Ballard et al. 2010). When prey is scarce, seabird adults are unable to find enough food to provision their chicks properly and this could lead to poor chick condition (Frere et al. 1998). Good condition chicks that fledge the nest have a better chance of survival than those in poor condition. The survival of young African penguins is crucial for the recruitment success into the population and the overall population growth. The condition of chicks will improve if the parents have access to sufficient food resources during the breeding season.. In a study done by Sherley et al. (2018) it was found that the closure of fisheries improved the condition of chicks.

3.5 Conclusion



The results in this study indicated a significant variability in chick condition between the two colonies, between years, across months and nest types. The condition index of chicks at Dyer Island was significantly poorer overall, compared to the condition index at Stony Point. Poor feeding conditions at Dyer Island during the breeding season might be the reason for poorer condition, as chick body condition can be used as an indicator of local food abundance (Lubbe et al. 2014). The mean monthly chick condition remained constant throughout the breeding season at Stony Point. A decline in the mean monthly chick condition towards the end of the breeding season was, however, noted at Dyer Island. The results indicated a difference in mean chick condition per nest type with the wooden box nest type the most successful nest type at Stony Point. The natural burrows were the least successful nest type at Stony Point. The vegetation nests had the highest mean chick condition at Dyer Island, compared to the artificial burrows with the lowest mean chick condition. The results indicated that nest types can influence chick body condition, therefore further studies should be done with regard to the design and placement of artificial nests at colonies. There was no correlation between chick

condition and overall breeding success at Stony Point, but there was a correlation found between chick and overall breeding success at Dyer Island. A lack of food resources could be the reason for this correlation - if parents have sufficient food, they can provide more resources to chick which can lead to an increase in chick body condition and breeding success.



CHAPTER 4 – FISH BIOMASS

4.1 Introduction

African penguins feed mainly on schooling pelagic fish, but their diet can also include cephalopods, horse mackerel (*Trachurus capensis*) and juvenile hakes (*Merluccius capensis*), (Hockey et al. 2005). Their primary prey species, however, are anchovy and sardine and their breeding and moult cycles are largely determined by the availability of these small pelagic resources (Crawford et al. 2006a). Connan et al. (2016) found that African penguin parents favour these small pelagic species due to their high energy content when they must catch food for their chicks during the breeding season. Anchovy and sardine of the order Clupeiformes occur in continental shelf waters between Hondeklip Bay on the West Coast and Durban on the East Coast (DEFF 2020). The South African sardine fish stock is further separated into the western stock distributed west of Cape Agulhas and the southern stock from Cape Agulhas to Port Alfred (Coetzee et al. 2019).

Anchovy feeds primarily on zooplankton like copepods and krill. The sardine diet includes phytoplankton and small zooplankton. Anchovy can reach a maximum size of 17 cm in length, while sardine can grow up to 30 cm in length (Branch et al. 2017). Anchovy spawning takes place on the Agulhas Bank from August to February, with the peak in November (Hampton 1987). Sardine can spawn year-round and will peak in September/October and February/March (Van der Lingen and Hugget 2003). The western sardine stock spawns offshore between Cape Agulhas and Cape Columbine and the southern stock spawns offshore between Cape Agulhas and Algoa Bay (Van der Lingen and Hugget 2003). Anchovy and sardine larvae are transported northwards along the West Coast in a current that develops west and south of Cape Point, but

once they can swim, they will form shoals. The juvenile anchovy fish migration (southwards along the west coast of South Africa) occurs between May until September of the year following spawning (Barange et al. 1999). Sardine juveniles congregate inshore of the West Coast before moving southwards during later summer or early autumn (Coetzee et al. 2019). The warm Agulhas and cold Benguela current are characterised by different oceanographic conditions, these differences can also influence the trophic ecology of the African penguin (Connan et al. 2016). Pelagic fish will respond strongly to environmental variability which result in natural fluctuations in abundance over space and time (DEFF 2020). Environmental factors such as water temperature can affect the transportation of eggs, larvae and feeding conditions, which in turn will affect the abundance of the species (DEFF 2020). The South African sardine stock crashed in the early 1960s due to overfishing, but gradually increased again with a peak in the early 2000s (Coetzee et al. 2008). Successive years of low recruitment has, however, resulted in a greatly reduced biomass and the stock is currently considered depleted (DEFF 2020). Anchovy stocks are considered optimal, but the biomass varies considerably from year to year (DEFF 2020).

There was a shift in the distribution of anchovy and sardine towards the east of the Agulhas Bank (Coetzee et al. 2008). The shift in distribution could be due to changes in sea surface temperatures and winds that may have affected the spawning conditions (Coetzee et al. 2008). Intensive fishing of sardine by commercial purse-seine fisheries also contributed to the reduction in biomass (Coetzee et al. 2008). Fish surveys are conducted twice-yearly by the Department of Forestry, Fisheries, and the Environment (DFFE). These surveys provide estimates of the available biomass measured in millions of tonnes (DEFF 2020). The biomass estimates obtained from these surveys form the basis for the recommendation of the annual total allowable catch for anchovy and sardine (Coetzee et al. 2019). The distribution and

abundance of these pelagic shoaling fish have been shown to affect various African penguin demographic processes. The abundance of anchovy and sardine is known to influence the breeding success and juvenile and adult survival of the African penguin (Crawford et al. 2006c; Sherley et al. 2013). The population trend and breeding success of the African penguin in the Western Cape has been linked with the abundance of sardine and anchovy (Coetzee et al. 2019). Research has shown that adult penguin mortality increases when the anchovy and sardine biomass fall below 25% of the maximum recorded value (Robinson et al. 2015). Crawford (1998) found a trend in the regional population numbers of the African penguin due to long-term changes in the abundance, distribution and availability of anchovy and sardine. The purse-seine industry can also reduce food availability, particularly during years when food abundance is poor (Pikitch et al. 2012). During times of food shortages penguin parents will provide less food to maintain chick survival, thus resulting in chicks with an extremely poor condition (Piatt et al. 2007). The closing of fisheries around penguin colonies can, however, improve chick condition and survival of African penguins (Sherley et al. 2018). The aim of this chapter was to investigate the relationship between anchovy and sardine fish biomass as measured by the bi-annual DFFE surveys and the breeding success and chick condition of African penguins at Stony Point and Dyer Island.

4.2 Methods

4.2.1 Fish biomass data

All the fish biomass data used in this chapter were provided by DFFE. The distribution and biomass of sardine and anchovy were assessed using hydro-acoustic surveys (Coetzee et al. 2019). The surveys have been conducted yearly since 1984 by the Department of Forestry, Fisheries and Environment (DFFE). Two surveys are conducted annually to estimate

distribution and biomass of anchovy and sardine (Coetzee et al. 2019). The survey is usually conducted during the month of May from the Orange River to Cape Infanta to determine spawner biomass (Figure 4.1). In November the survey is conducted from Hondeklip Bay to Port St Johns to determine the total adult biomass (Figure 4.2). The surveys consist of a series of pre-stratified, parallel transect, randomly spaced tracks designed to obtain an unbiased estimate of the biomass (Hampton 1987). The area is divided into ten strata for spawner biomass surveys in May ranging from the Orange River to Hondeklip Bay (Stratum A), Hondeklip Bay to Doring Bay (Stratum B), Doring Bay to Cape Columbine (Stratum C), Cape Columbine to Cape Point (Stratum D), Cape Town to Cape Agulhas (Stratum E, used in this study), Cape Agulhas to Cape Infanta (Stratum F), Cape Infanta to Mossel Bay (Stratum G), Mossel Bay to Port Elizabeth (Stratum H), Port Elizabeth to Port Alfred (Stratum I) and Port Alfred to Port St Johns (Stratum J), (Coetzee et al. 2019). During the November adult biomass survey the area is divided into six strata from Hondeklip to Cape Columbine (Stratum A), Cape Columbine to Cape Point (Stratum B), Cape Point to Cape Agulhas (Stratum C, used in this study), Cape Agulhas to Mossel Bay (Stratum D), Mossel Bay to Port Alfred (Stratum E) and Port Alfred to Port St Johns (Stratum F).

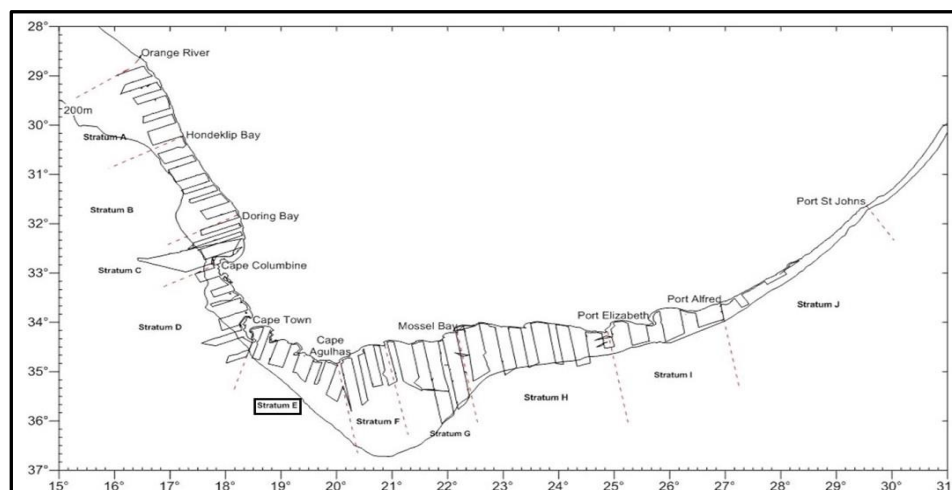


Figure 4.1: Stratums surveyed during May, with Stratum E used in this study (Coetzee et al. 2020).

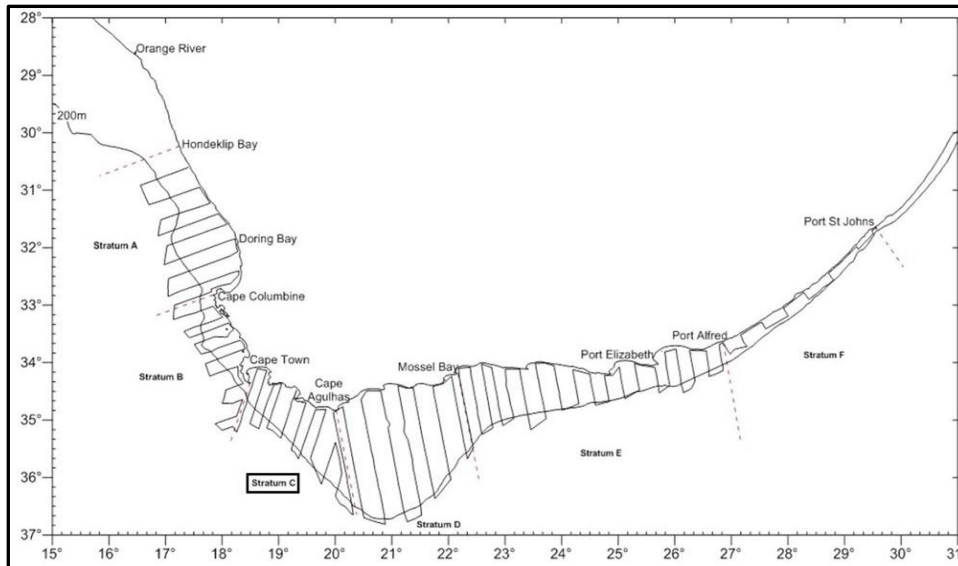


Figure 4.2: Stratums surveyed in November, with Stratum C used in this study (Coetzee et al. 2020).

Anchovy and sardine data from Stratum E (Cape Point to Cape Agulhas) of the May recruitment biomass survey were used in this study for Stony Point from 2013 to 2019 and Dyer Island from 2008 to 2019. Anchovy and sardine stratum C data (Cape Point to Cape Agulhas) of the November spawner biomass surveys were also used for Stony Point (period 2013 to 2019) and Dyer Island (period 2008 to 2019). The overlap between the areas where penguins from Stony Point and Dyer Island forage in relation to the total length of the fish biomass transects surveyed was small (Figure 4.3). The relationship between chick condition and breeding success with catch data was also investigated, but no significant relationship was found. The catch data used were collected by DFFE from landings from the small pelagic fishery for the period 2008 to 2019 at a radius of 10, 20, 30 and 40 nautical miles from each colony.

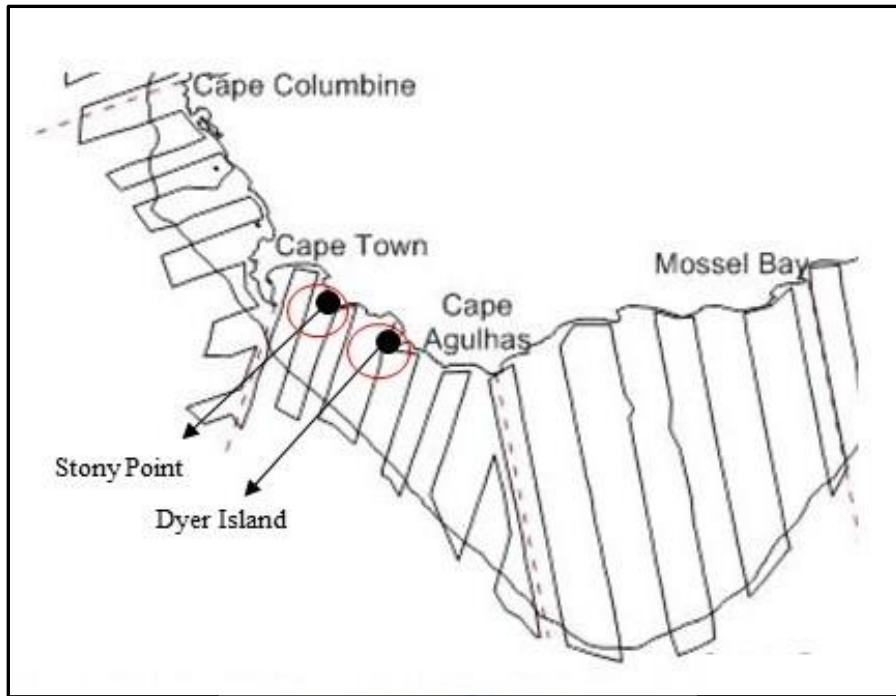


Figure 4.3: Location of Stony Point and Dyer Island in relation to tracks followed during the 2020 surveys for November conducted by DFFE within the 20 nautical mile radius in red where penguins forage (Coetzee et al. 2020).

4.2.2 Penguin data

Breeding African penguins forage every day and are range-restricted when doing so (Seddon and van Heezik 1991). Any correlation between fish biomass data and chick condition and breeding success data are likely to show when food is scarce because African penguins during the breeding season, are more restricted when foraging than seabirds able to fly (Pichegru et al. 2009). The adults must therefore make a greater effort to find enough food for their chicks. Chick condition can be used as an indicator of local food abundance (Lubbe et al. 2014), therefore the relationship between overall chick condition and fish biomass were investigated. Previous research has shown that African penguin sibling chicks can grow at similar rate when food availability is high (Seddon and van Heezik 1991). However, when food is scarce the amount of food that is delivered to the second hatchling may be insufficient and the older chick is able to outcompete the smaller chick for food (Seddon and van Heezik 1991). The B-chick can therefore be a better indicator of food availability than the A-chick. Based on the above

assumptions the relationship between fish biomass and the B-chicks were investigated. African penguin breeding pairs must compete with each other as well as with other seabirds and the pelagic fisheries for food resources during each breeding season. The relationship between fish biomass available per census pair and chick condition were also investigated. Body condition data of penguin chicks collected from the period 2013 to 2019 at Stony Point, and for the period of 2008 to 2019 at Dyer Island were used. Breeding success data, which was collected between 2013 and 2019 at Stony Point and at Dyer Island data between 2008 and 2019, were used.

4.2.3 Data analysis

The R-Squared test (coefficient of determination) to determine whether there was any correlation between fish biomass and penguin chick condition as well as breeding success, was used.



4.3 Results

4.3.1 Correlation between fish biomass and chick condition

The mean chick condition measurements for each year at Stony Point and Dyer Island were compared with the fish biomass for anchovy and sardine collected in May (Stratum E) and November (Stratum C) indicated in Table 4.1. At Stony Point no correlation was found between chick condition and the May ($R^2 = 0.009$) and November ($R^2 = 0.005$) anchovy biomass. The November sardine biomass ($R^2 = 0.008$) also showed no correlation, but there was, however, a weak negative correlation between chick condition and May's sardine biomass at Stony Point ($R^2 = -0.050$). The results for Dyer Island showed no correlation between November anchovy biomass and chick condition ($R^2 = 0.001$). There was, however, a weak negative correlation

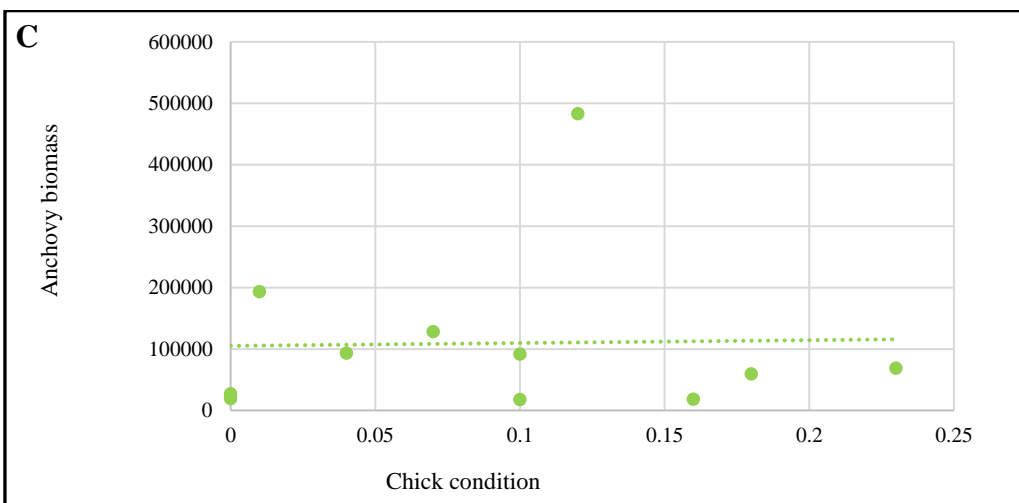
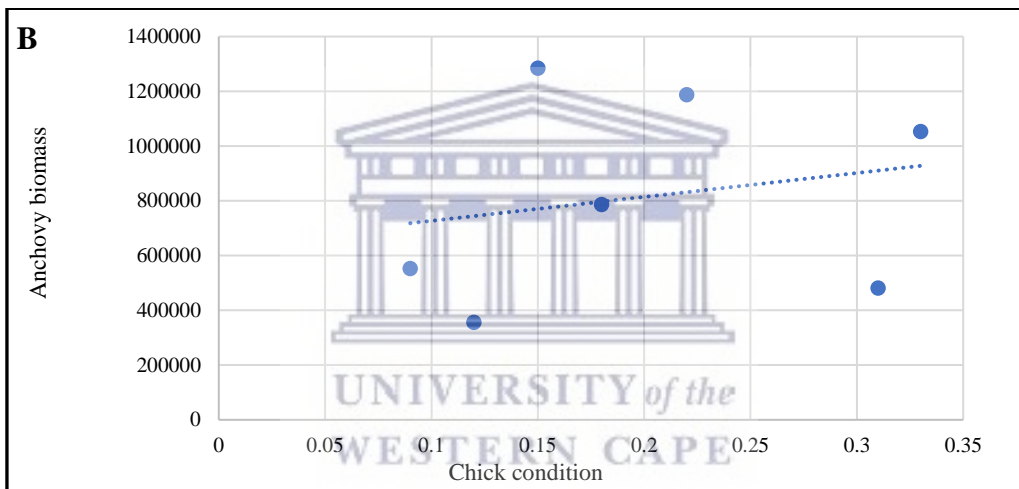
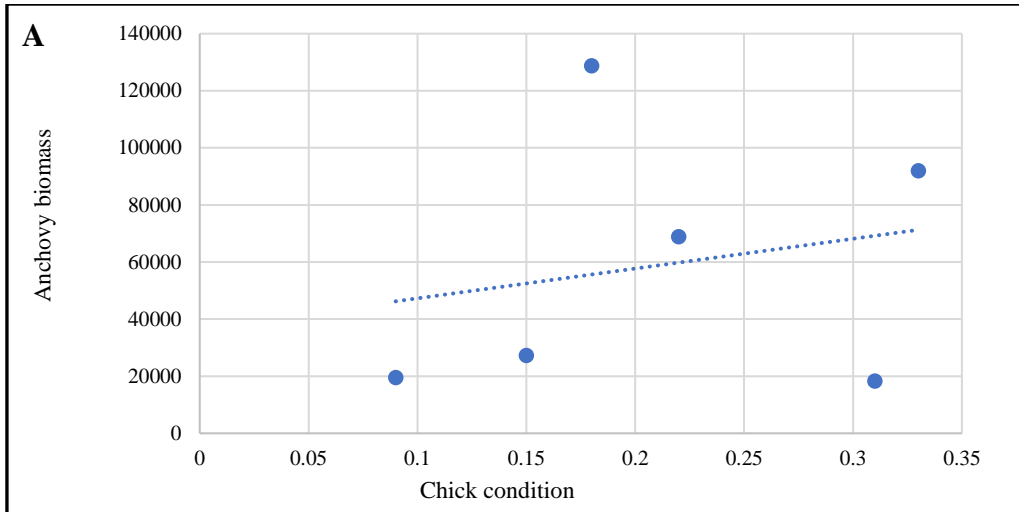
found for May's anchovy biomass and chick condition, as well as May and November's sardine biomass at Dyer Island.

Table 4.1: Summary statistics of fish biomass (period 2008 to 2019) and chick condition for Stony Point (period 2013 to 2019) and Dyer Island (period 2008 to 2019).

Category	Anchovy Biomass		Sardine Biomass		Anchovy Biomass		Sardine Biomass	
	May		May		November		November	
	R ²	Correlation	R ²	Correlation	R ²	Correlation	R ²	Correlation
<u>Stony Point</u>								
All chicks	0.009	N	0.050	W NEG	0.005	N	0.008	N
B-chicks	0.046	W	0.000	N	0.048	W	0.308	S
B-chicks/pairs in census	0.114	W	0.088	W	0.107	W	0.336	S
<u>Dyer Island</u>								
All chicks	0.024	W NEG	0.015	W NEG	0.001	N	0.048	W NEG
B chicks	0.001	N	0.035	W NEG	0.003	N	0.003	N
B-chicks/pairs in census	0.018	W NEG	0.020	W NEG	0.004	N	0.000	N

S – Strong correlation, W – Weak correlation, N – No correlation, S NEG – Strong negative correlation, W NEG – Weak negative correlation

Investigating the relationship between fish biomass and the condition of the B-chick indicated a weak correlation between anchovy fish biomass and the condition of the B-chick at Stony Point for May ($R^2 = 0.046$, Figure 4.4A) and November ($R^2 = 0.048$, Figure 4.4B). There was no correlation at Dyer Island between the B-chick and anchovy biomass for May ($R^2 = 0.001$, Figure 4.4C) and November ($R^2 = 0.003$, Figure 4.4D).



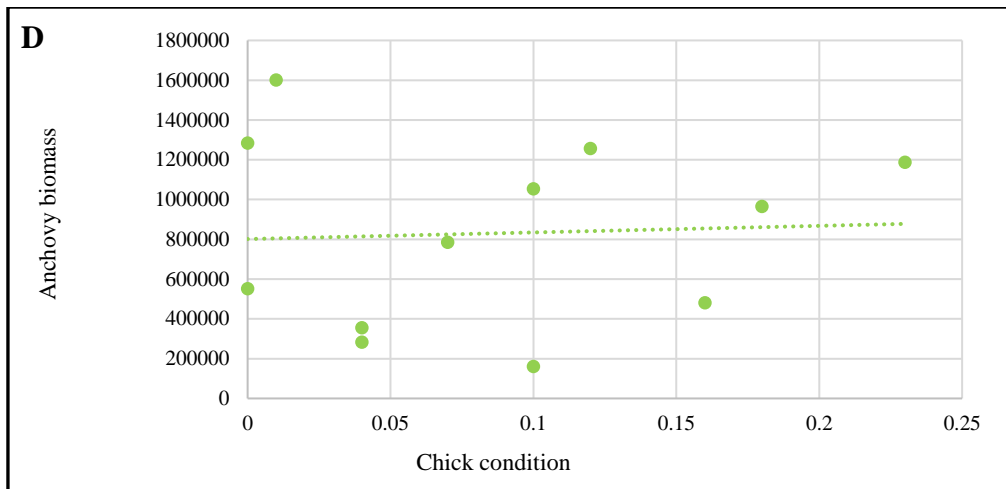
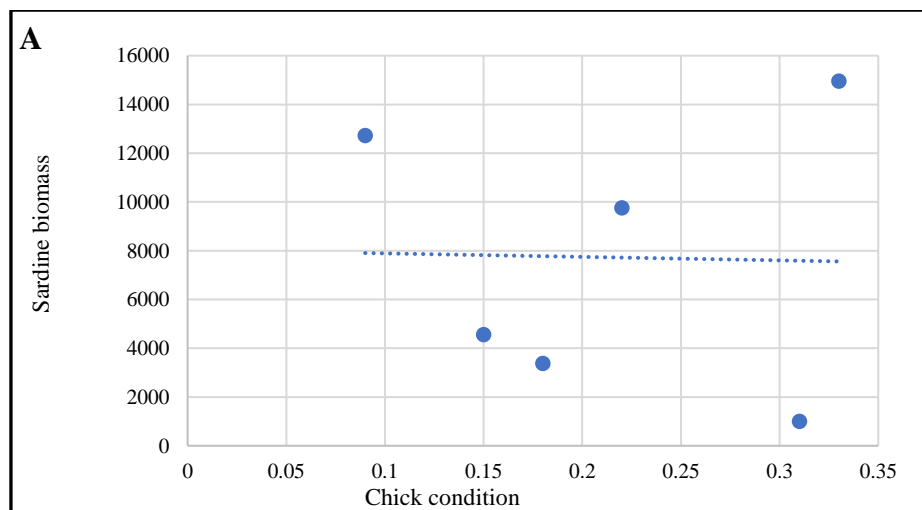


Figure 4.4: Correlation between mean chick condition of B-chick per year and anchovy biomass tonnes per year for surveys done in May (A) and November (B) at Stony Point (period 2013 to 2019) and surveys done in May (C) and November (D) at Dyer Island (period 2008 to 2019).

The May sardine biomass and B-chick showed no correlation at Stony Point ($R^2 = 0.000$, Figure 4.5A). There was, however, a strong correlation between the B-chick and sardine fish biomass for November at Stony Point ($R^2 = 0.308$, Figure 4.5B). The results for Dyer Island indicate a weak negative correlation with the B-chick at Dyer Island and sardine fish biomass for November ($R^2 = -0.035$, Figure 4.5C). There was no correlation between November sardine fish biomass and B-chick condition at Dyer Island ($R^2 = 0.003$, Figure 4.5D).



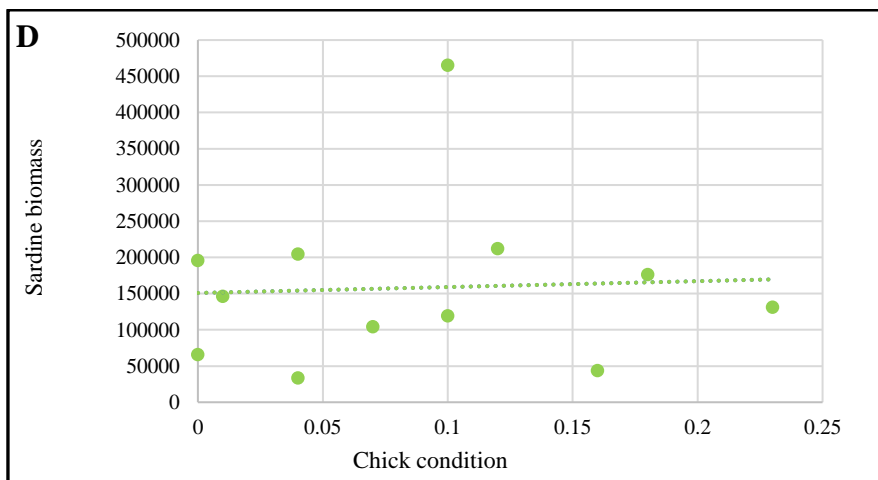
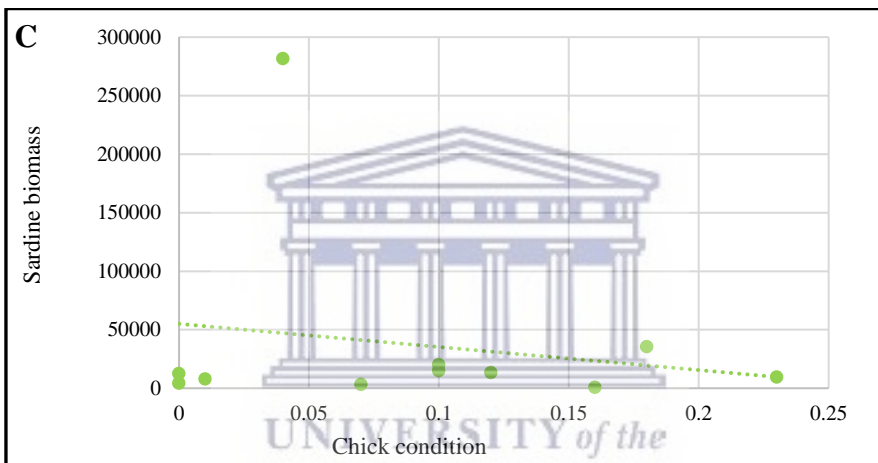
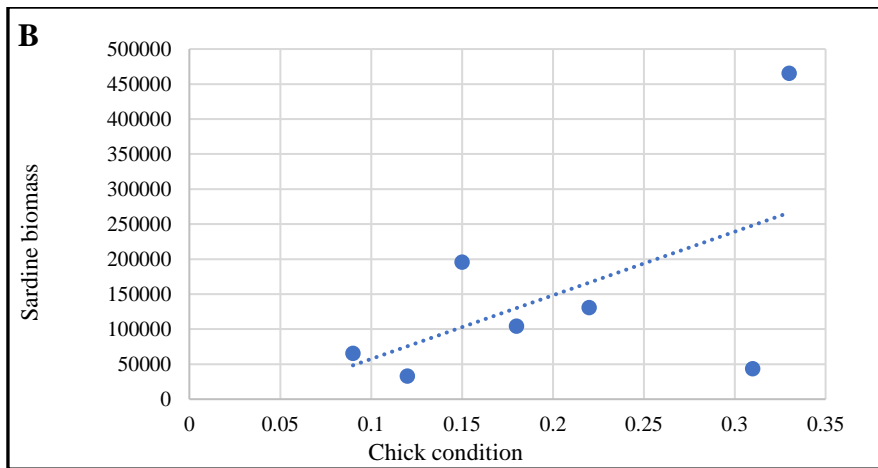


Figure 4.5: Correlation between mean chick condition of B-chick per year and sardine biomass tonnes per year for surveys done in May (A) and November (B) at Stony Point (period 2013 to 2019) and for surveys done in May (C) and November (D) at Dyer Island (period 2008 to 2019).

4.3.2 Correlation between fish biomass per census pair and chick condition

African penguins rely on adequate local food resources throughout the breeding season (Sherley et al. 2013). The available food resources must also be shared amongst the colony; therefore, the size of the colony can influence how much food will be available for each breeding pair. If resources are inadequate, it can influence the condition of the B-chick and therefore the condition of the B-chick was also compared with fish biomass available per census pair. The results showed weak correlations at Stony Point for May and November anchovy biomass as well as May's sardine biomass (Table 4.1). There was, however, a strong correlation ($R^2 = 0.336$, Figure 4.6) between the condition of the B-chick and November's sardine biomass available per census pair. The results at Dyer Island for the B-chick and fish biomass per census pair showed only weak negative correlations for May's sardine and anchovy biomass, and no correlation for November's anchovy and sardine biomass (Table 4.1).

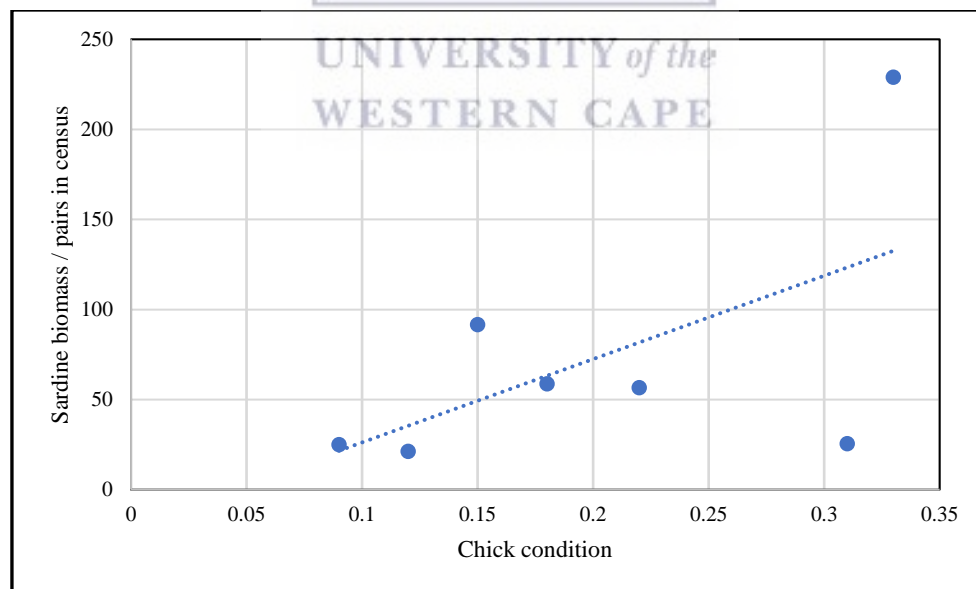


Figure 4.6: Correlation between mean chick condition of B-chick per year and sardine biomass tonnes available per census pairs per year for fish biomass surveys done in November at Stony Point (period 2013 to 2019).

4.3.3 Correlation between fish biomass and breeding success

The mean hatching, fledging and overall breeding success were compared with the fish biomass for anchovy and sardine collected in May and November. The results showed very weak correlations between overall breeding success and fish biomass at both Stony Point and Dyer Island (Table 4.2). There were correlations between fish biomass and hatching as well as fledging success at Stony Point. Dyer Island data showed only very weak correlations and some of the correlations were negative (Table 4.2).

Table 4.2: Summary statistics of fish biomass and breeding success for Stony Point (period 2013 to 2019) and Dyer Island (period 2008 to 2019).

Category	Anchovy Biomass		Sardine Biomass		Anchovy Biomass		Sardine Biomass	
	May		May		November		November	
	R ²	Correlation	R ²	Correlation	R ²	Correlation	R ²	Correlation
<u>Stony Point</u>								
Overall breeding success	0.021	W	0.019	W	0.012	W	0.007	W
Hatching success	0.163	W	0.103	W	0.104	W	0.458	S
Fledging success	-0.386	S NEG	0.043	W	-	S NEG	0.563	S NEG
<u>Dyer Island</u>								
Overall breeding success	-0.019	W NEG	0.011	W	0.001	N	0.018	W
Hatching success	-0.012	W NEG	0.040	W	0.044	W NEG	0.022	W
Fledging success	-0.057	W NEG	0.050	W	0.017	W NEG	0.024	W NEG

S – Strong correlation, W – Weak correlation, N – No correlation, S NEG – Strong negative correlation, W NEG – Weak negative correlation

There was a correlation between hatching success and fish biomass at Stony Point. An increase in fish biomass resulted in an increase in hatching success, with the hatching success plateauing at 0.95 (Figures 4.7 to 4.9). The results of the fledging success showed a negative correlation

with fish biomass at the Stony Point colony. The anchovy biomass and fledging success for May showed a strong negative correlation ($R^2 = -0.386$, Figure 4.7). The November anchovy biomass and fledging success had a similar negative correlation ($R^2 = -0.395$, Figure 4.8). The November sardine biomass showed a very strong correlation with hatching success ($R^2 = 0.458$) and a very strong negative correlation with the fledging success ($R^2 = -0.563$, Figure 4.9).

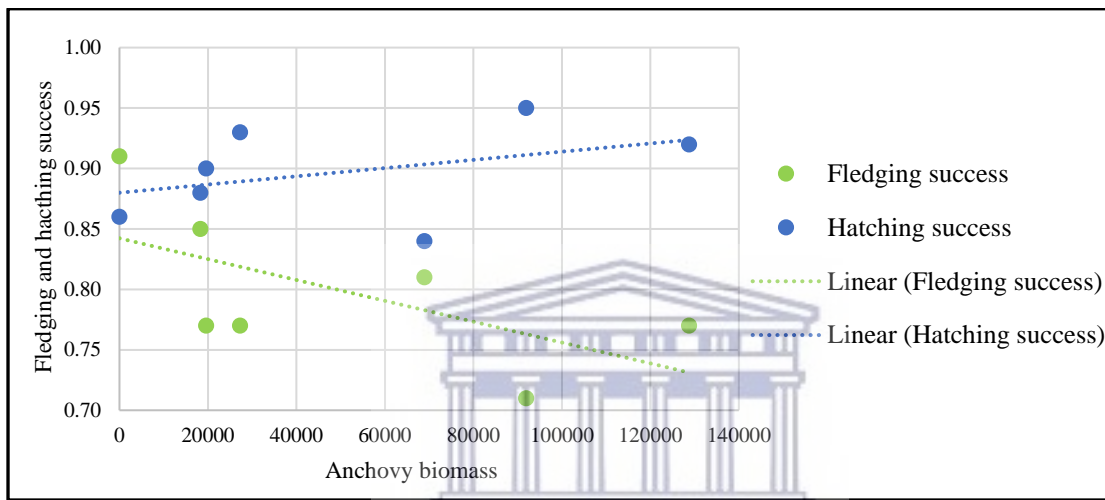


Figure 4.7: Correlation between mean fledging success and hatching success and anchovy biomass tonnes per year for fish biomass surveys done in May at Stratum E for Stony Point (period 2013 to 2019).

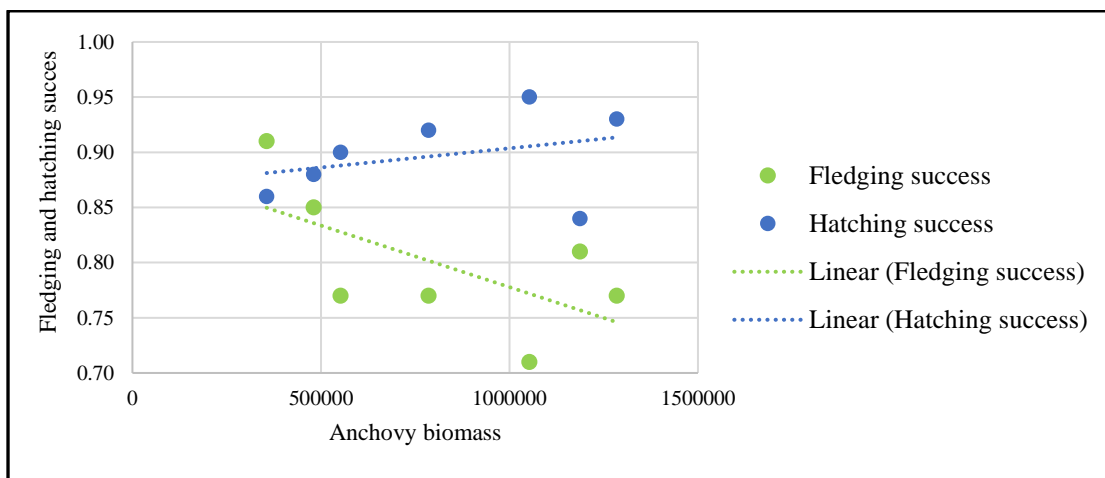


Figure 4.8: Correlation between mean fledging success and hatching success and anchovy biomass tonnes per year for fish biomass surveys done in November at Stratum C for Stony Point (period 2013 to 2019).

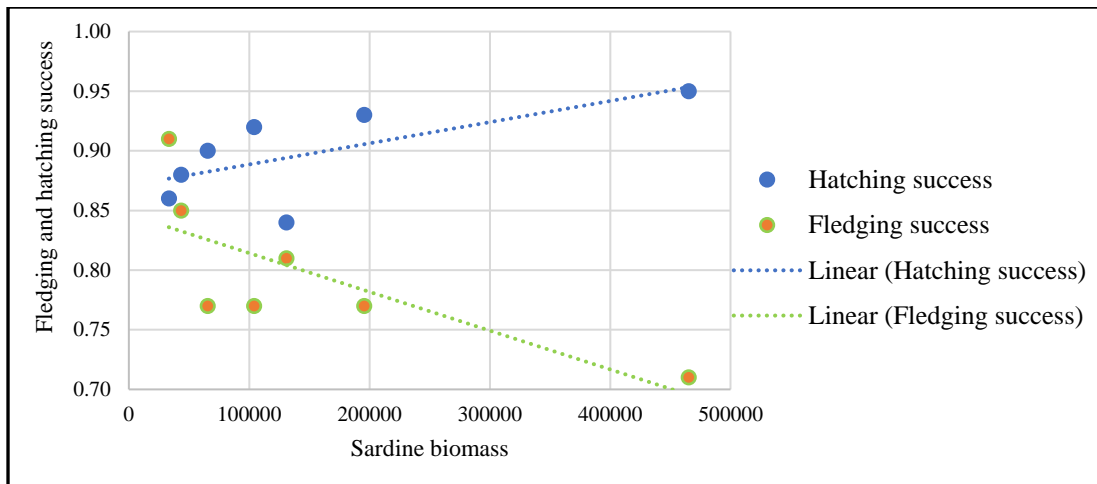
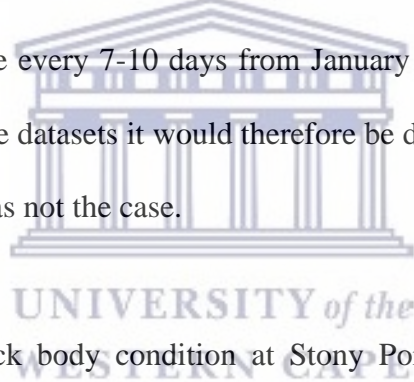


Figure 4.9: Correlation between mean fledging success and hatching success and sardine biomass tonnes per year for fish biomass surveys done in November at Stratum C for Stony Point (period 2013 to 2019).

4.4 Discussion

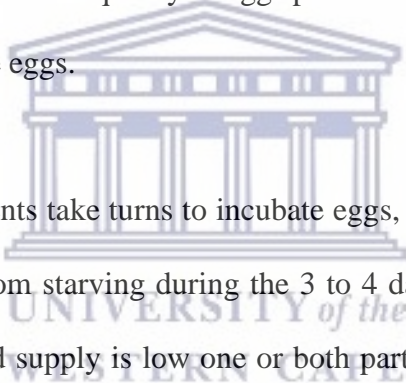
Seabirds form part of the marine ecosystem and some species have strong dietary dependence on fish (Cury et al. 2011). There is a number of published work highlighting the relationship between prey availability and seabird demographic parameters. For example the foraging behaviour of the Little penguin was related to the chick fledging weights, the adults had shorter foraging trips during chick rearing but the birds that were forced to travel longer distance due to limited prey availability showed a decrease in chick condition and fledging success (Saraux et al. 2011). When investigating the common murre (*Uria aalge*) and black-legged kittiwake (*Rissa tridactyla*) fledglings, a non-linear relationship was found between chick body condition and prey density (Piatt et al. 2007). The foraging effort of Cape gannets (*Morus capensis*) increased, and nest attendance decreased when there was a reduction of anchovy and sardine in their diet (Crawford et al. 2019). Cape gannet chicks that were fed sardine also consumed less food but had higher fledging masses than those fed hake (Batchelor and Ross 1984).

The global African penguin population has declined over the last 30 years from 51 500 pairs in 1989 to 10 400 pairs in 2021 (Sherley et al. 2020; Sherley et al. 2021). The lack of prey (predominantly small pelagic fish such as sardine and anchovy) is believed to be the main contributing factor to this decline (Sherley et al. 2017; Crawford et al. 2018). Prey interaction studies with African penguins have been investigated with transects and boat observations (Wilson et al. 1988; Crawford et al. 2006a; Ryan et al. 2012). In this study the relationship between fish biomass and African penguin chick condition as well as breeding success were investigated at Stony Point and Dyer Island. As described in Methods (4.2) the acoustic survey is only done twice a year following a series of randomly spaced tracks, whereas the chick condition measurements are done once a month from March to November. The breeding success measurements are done every 7-10 days from January to October. Given the spatial and temporal difference in these datasets it would therefore be difficult to find any correlation between the dataset, but this was not the case.



The results indicated that chick body condition at Stony Point was related to local prey abundance and, chick body condition of the B-chick decreased when pelagic fish were locally less abundant (Table 4.1). The condition of the B-chick at Stony Point also showed a decrease when the amount of fish biomass per census pair decreased. The amount of nourishment the parents can feed their chicks will relate to the ease with which they can find and catch fish of high nutritional value (Sherley et al. 2020). Limited food resources can slow down the growth rates of the African penguin and cause starvation, and the B-chicks are more susceptible to death from starvation (Seddon and van Heezik 1993). Campbell et al. (2019) also found a decrease in chick body condition at Robben Island as prey abundance declined.

The results indicated that hatching success was related to the local prey abundance, the hatching success increased when pelagic fish biomass increased (Table 4.2). Fledging success was also related to the abundance of local prey species but negatively; the fledging success decreased when pelagic fish biomass increased. Female penguins need to have sufficient energy during the pre-egg laying phase to be able to produce an egg, otherwise they will have to draw on their body reserves to form and lay an egg (van Heezik and Seddon 1991). Even during times of poor food supply egg production will still take place from some birds, the eggs could, however, have imperfections or be infertile. When food supply decreases some females might not be able to produce eggs, thus as prey biomass decrease unfit birds will not be able to lay eggs at all. Therefore when food supply is low the quality of eggs produced could be higher because only fit females were able to produce eggs.



During incubation penguin parents take turns to incubate eggs, they need to be able to forage enough fish to prevent them from starving during the 3 to 4 days during of their incubation shift (Randal 1983). When food supply is low one or both partners might abandon the egg/s due to starvation, leading to low hatching success. If energy reserves are too low, long-living seabirds will prioritize self-maintenance and their own survival, rather than focusing on reproduction (Ballard et al. 2010). As fish availability increases adults should be able to hatch eggs without losing body condition, thus leading to an increase in hatching success. During exceptionally low food supply only the fittest birds will successfully hatch their eggs, as food supply increases, the less fit birds will also be able to hatch their chicks.

Once chicks have hatched, they demand increasing amounts of food, so the parents must steadily increase their foraging efforts (Salton et al. 2015). If the parents can build up energy reserves before the onset of breeding, they may be able to buffer any changes in food

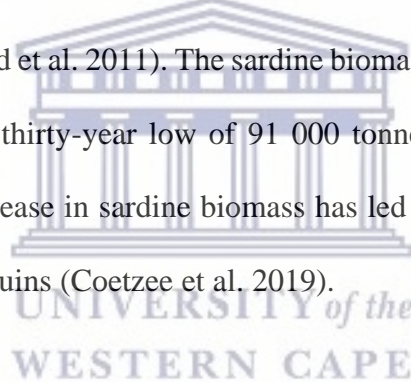
availability throughout the breeding season and maintain their own reserves while still providing for their chicks (Robinson et al. 2005). If one parent has a low body mass it will not be able to provide an equal foraging amount of effort, thus the partner will have to be in a good enough condition to compensate and continue feeding the chicks (Randal 1983). The nest will be at risk of failing during the fledging stage because the parent in poor condition will need to spend a longer time at sea to build up its own reserves (Clarke 2001). The partner attending to the nest may leave it to avoid starvation if not relieved in time. This in turn could leave the nest content vulnerable and lead to breeding failure (Numata et al. 2000).

In good food years when there is enough food available for parents to forage without significant loss of body condition, one would expect fledging success to increase with an increase in fish biomass. But this is not reflected in the results; there could be several reasons for fledging success showing a negative correlation with fish biomass. It could be that the birds that have successfully hatched their eggs may have already exerted themselves and lost condition doing that, so that they do not have sufficient reserves left to successfully rear their chicks. Randall (1983) found that adequate energy reserves throughout the breeding season is vital to ensure successful rearing of chicks. It is likely that the birds that managed to successfully hatch their eggs during low food supply are the “good quality” birds; they may be better foragers and more experienced parents (Wilson 2009)

As the food supply increases the impact of the quality of parents may decrease as even the underperforming birds then have to draw less on their reserves to successfully hatch eggs, consequently the more food is available even the more underperforming birds may manage to hatch eggs. But during the chick rearing stage they must work increasingly harder to provide food and are not able to do so. This can result in them losing their chicks and this may possibly

explain why the results of the chick rearing success is low even when the egg hatching success and fish biomass are higher. These results indicate that the availability of prey such as anchovy and sardine does have an impact on the condition of chicks as well as hatching and fledging success.

The total allowable catch (TAC) for sardine and anchovy are set at the beginning of the fishing season by DFFE, based on the previous November biomass survey (Coetzee et al. 2019). The TAC for anchovy is revised mid-year following the completion of the May recruitment survey, because anchovy fishery is largely a recruit fishery (Coetzee et al. 2019). African penguin populations along the west coast showed an increase around the 1990s when the sardine in the region were abundant (Crawford et al. 2011). The sardine biomass has, however, declined from 4 million tonnes in 2002 to a thirty-year low of 91 000 tonnes in 2018 due to overfishing (Coetzee et al. 2019). The decrease in sardine biomass has led to a decrease in abundance of Cape gannets and African penguins (Coetzee et al. 2019).



When the sardine spawner biomass fell below 25% of its maximum observed value west of Cape Agulhas, the survival of adult African penguins at Robben Island markedly decreased (Robinson et al. 2015). The breeding success of Cape gannets and African penguins decreased when the combined biomass of anchovy and sardine was less than about one-third of its maximum observed value (Cury et al. 2011). Another study found that African penguin breeding number are 50% lower in areas where fishing stock is low (Sherley et al. 2017). It should therefore be considered to adjust and reduce the total allowable catch during low fish biomass years as a measure to reduce competition with fisheries and scares food resources, thus increasing the opportunities for penguins to obtain sufficient food even in poor food years.

African penguins are in critical need of conservation action due to the continuing decline in population numbers. Access to sufficient food has been identified as a leading cause of the recent declines (BirdLife International 2021). Conservation action therefore needs to include enhancing marine spatial planning to improve access to sufficient food resources for penguins (Boersma et al. 2019). An international review on the impact of forage fish abundance on marine predators suggested that the closures around breeding sites could be more effective than other more broad-scale interventions (Free et al. 2021). Previous studies found that “no take” fishing zones can benefit the African penguin in terms of a decrease in foraging effort by the parents which result in an increase in chick condition and growth of the chicks (Pichegru et al. 2010; Sherley et al. 2020). It was also found that the closing of fisheries around penguin colonies improved chick condition and survival of African penguins although it was inconsistent across sites and years (Sherley et al. 2018). The stability of breeding numbers at Simonstown due to the prohibition of pelagic fishing, provided circumstantial evidence in support of closing fisheries around penguin colonies (Sherley et al. 2020). The results indicated biologically meaningful effects on variables like chick survival and fledging success (Sherley et al. 2020). Fishing exclusion around St Croix Island has reduced the energy spent by breeding birds foraging (Pichegru et al. 2012).

According to Koehn et al. (2021) seabirds have evolved to cope during low prey periods, if these lows, however, increase in frequency and/or are prolonged it could lead to a significant reduction in the population. Therefore, fishing closures around penguin colonies (specifically during the years when food resources are low) should be considered as a conservation measure to be implemented to ensure the future of the species (Crawford et al. 2015). An increase in chick survival and growth can be used as a measurement to determine the effectiveness of fishing closure areas (Boersma et al. 2015).

4.5 Conclusion

Only weak negative correlations were found when comparing chick body condition measurements with sardine and anchovy fish biomass collected in May and November at each colony. When investigating the relationship between fish biomass and chick body condition for the B-chick, a strong positive correlation was found at Stony Point between the body condition of the B-chick to the November sardine biomass. There was also a strong positive correlation between November sardine biomass available per census pair and the condition of the B-chick at Stony Point. The results indicated that chick body condition at Stony Point was related to local prey abundance where chick body condition of the B-chick increased when there was an abundance in local pelagic fish. The condition of the B-chick at Stony Point also increased when the amount of fish biomass available per census pair increased. The results suggested a difference in feeding conditions between Stony Point and Dyer Island. At Stony Point there was also a correlation found between hatching success and fish biomass. The results suggested an increase in hatching success when fish biomass increased. Fledging success, however, showed a negative correlation with fish biomass at Stony Point where fledging success decreased when pelagic fish biomass increased. Access to adequate fish resources during the breeding season is vital to ensure that chicks are reared successfully.

CHAPTER 5 – SUMMARY AND RECOMMENDATIONS

5.1 Introduction

Penguin species across the world are facing a range of threats including limited food resources, climate change, habitat degradation, pollution from oil spills, predation and human disturbance (Trathan et al. 2015; Dias et al. 2019). It is important to assess the impact of these threats on species' demographic processes and when management interventions are implemented, to monitor the efficacy thereof. The aim of this thesis was to examine the breeding success and chick condition of African penguins at Stony Point (main land colony) and Dyer Island (island colony) and identify which factors could influence breeding success and chick condition. The study was done to contribute to the analysis of long-term monitoring of demographic data, an action as per the Biodiversity Management Plan for the African penguin (DEA 2019). Breeding success, chick body condition and fish biomass data for the period 2013 to 2019 was used for Stony Point, and for the period 2008 to 2019 for Dyer Island.

5.2 Key findings

5.2.1 *Breeding success*

Breeding success was calculated using an extension of the Mayfield (1961) method developed by Sherley et al. (2012a). Chapter 2 showed that there was no significant difference in hatching success between the years and the two colonies. Fledging success and overall breeding success, however, showed a large variability between the years and the colonies. The results showed that mean fledging success and overall breeding success were significantly higher at Stony Point than Dyer Island. The number of days chicks required to fledge the nest showed a variation between the years and the colonies. The average fledging period was shorter at Stony

Point compared to Dyer Island. At both colonies the days required to fledge decreased towards the end of the breeding season. The overall breeding success showed a variation between the months, but at both colonies the success rate was low at the start and end of the breeding season. The wooden box nest type was the most successful nest type at both colonies with the highest overall breeding success.

5.2.2 Chick condition

The body condition of chicks was explored in Chapter 3, where chick condition was calculated using the body condition index developed by Lubbe et al. (2014) to assess samples of chicks of various ages and sizes. There was significant variability in chick condition between the two colonies, between years, across months and nest types. The condition index of chicks at Dyer Island was significantly poorer overall, compared to the condition index at Stony Point. This suggests that feeding conditions are poorer at Dyer Island. The mean monthly chick condition at Dyer Island showed a decline towards the end of the breeding season, compared to Stony Point where the mean chick condition stayed constant throughout the season. At Stony Point the wooden box nest type was the most successful nest type with the highest mean chick condition, while the natural burrows were the least successful nest type. The vegetation nests had the highest mean chick condition at Dyer Island, compared to the artificial burrows with the lowest mean chick condition.

5.2.3 Fish Biomass

In Chapter 4 the relationship between anchovy and sardine biomass and the breeding success and chick condition was investigated. During the breeding season African penguins rely on food resources close to the colony to ensure successful breeding and good body condition of the chicks. The results suggested that feeding conditions are not similar at Stony Point and

Dyer Island. The body condition of the B-chick at Stony Point was positively related to November sardine biomass. There was also a strong positive correlation between November sardine biomass available per census pair and the condition of the B-chick at Stony Point. The results indicated that chick body condition at Stony Point was related to local prey abundance; chick body condition of the B-chick increased when there was an abundance in local pelagic fish. The condition of the B-chick at Stony Point also increased when the amount of fish biomass available per census pair increased. At Stony Point there was a correlation between hatching success and fish biomass. The results suggested an increase in hatching success when fish biomass increased. Fledging success, however, showed a negative correlation with fish biomass at Stony Point where fledging success decreased when pelagic fish biomass increased.

5.3 Recommendations

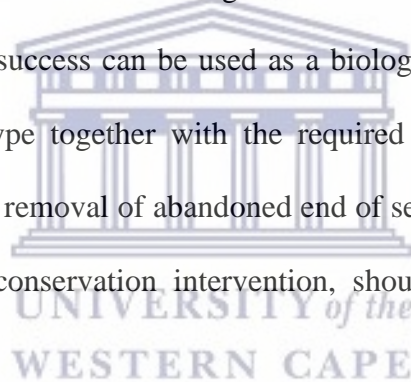


5.3.1 Management recommendations

Direct management in conjunction with education and community engagement can play an important role in the conservation of seabird populations (Lewison et al. 2012). It is important to limit the mortality of African penguin eggs and chicks during the breeding season in an effort to increase breeding success. Therefore, possible mortality causes such as predation, high temperatures, flooding and hypothermia and food availability should be reduced.

Managing authorities should have a predation strategy for each possible predator of penguins at each African penguin colony that includes the measures that should be implemented to control the predation. It is important to monitor the colonies regularly for predators and activate the appropriate predator control measures immediately. Extreme weather conditions can influence breeding success and chick condition. It is therefore important to implement

measures to reduce the impact of heat, flooding, and hypothermia. Weather forecasts should be monitored and the drainage lines opened up in colonies before heavy rainfall to ensure that run off is effective in an effort to limit the flooding of nests. During extreme cold and wet conditions, the nests should be monitored and young chicks in poor condition removed to limit the impact of hypothermia. Adequate nest cover to protect the adults and chicks from heat is also necessary. Nests covered by vegetation will reduce the temperature inside the nests (Tol 2015). The wooden box nest type, most successful at both colonies should be investigated further as a possible preferred nest type. Some of the current artificial nest types used do not mimic natural climatic conditions successfully (Lei et al. 2014). Colonies should select artificial nest types that is best suitable according to the environment of that specific colony. Chick condition and breeding success can be used as a biological measure to determine the most suitable artificial nest type together with the required physical monitoring such as temperature and humidity. The removal of abandoned end of season chicks to be hand-reared and released, an established conservation intervention, should continue at both colonies (Barham et al. 2007).



It is important that African penguins have access to adequate fish resources in close proximity to their colonies, especially during the breeding season. Therefore, competition with purse-seine fishing needs to be limited and the pressure reduced especially when food resources are low. Cochrane et al. (2004) found that an ecosystem approach towards fisheries (EAF) is required to ensure the long-term sustainability of the marine resources and the ecosystem. The ecosystem approach to fisheries recognises the interdependence between ecosystem health and human well-being.

Fishing closures around penguin colonies should be considered as a conservation measure to increase the pelagic fish biomass available to foraging penguins. Adjusting and reducing the total allowable catch during low fish biomass years could also be implemented. Dynamic ocean management (real-time management) should be considered as a measure to increase the efficacy and efficiency of fisheries management by aligning the human and ecological scales of use (Dunn et al. 2016). Management that changes rapidly in space and time in response to the shifting nature of the ocean and users are defined as dynamic ocean management (Maxwell et al. 2015). Dynamic ocean management can balance ecological and economic objectives by refining the temporal and spatial scale of management areas. It can complement management by increasing the speed at which decisions are implemented.

5.3.2 Research recommendations

The Steering Committee of the International Union for Conservation of Nature Species Survival Commission Penguin Specialist Group determined that the African penguin are one of the penguin species in most critical need of conservation action (Boersma et al. 2019). Research priorities to improve the translation of science into effective conservation, included population trends, forecasting environmental patterns of change and improving the knowledge of fisheries interactions (Boersma et al. 2019). The two colonies Stony Point and Dyer Island are only c. 60 km apart, but the results of this study indicated that breeding success rate was lower at Dyer Island and the chicks were in a poorer condition at Dyer Island compared to Stony Point. It will be useful to understand the population dynamics at Stony Point and why this colony is more successful compared to Dyer Island.

The predator prey dynamics of the African penguin needs more research. There is a need for small-scale fish biomass surveys to determine the distribution and abundance of small pelagic

fish species around colonies. The current fish biomass surveys are conducted only twice a year covering a large-scale area. The results of this study showed a relationship between the condition of chicks and fish biomass, body condition increased when there was an abundance of fish available. Hatching success increased along with an increase in fish biomass, but fledging success decreased when pelagic fish biomass increased at Stony Point. The relationship between chick condition, breeding success and fish biomass data collected at a smaller scale should be investigated further to determine correlations at a finer scale. The warm Agulhas and cold Benguela current are characterised by different oceanographic conditions; these differences can also influence the trophic ecology of the African penguin (Connan et al. 2016). Further research should take place to understand the trophic ecology (how it varies with time, location and age class) of the African penguin. Research should also focus on whether chick condition measurements (collected regularly at all colonies) can be used to determine the current fish biomass availability and implement as an indicator to adjust the total allowable catch during the season. The results from chick condition measurements can also serve as a baseline against which to monitor the impact of fishing closures.

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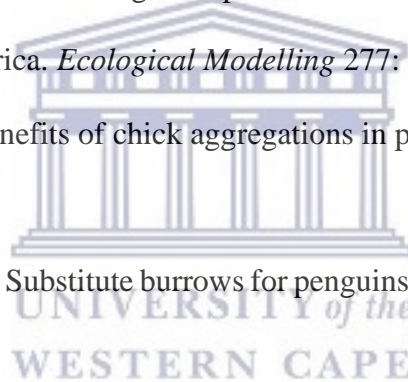
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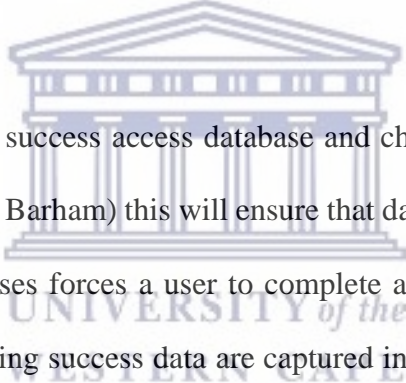
the rescue, rehabilitation and restoration of oiled seabirds in South Africa, especially African penguins *Spheniscus demersus* and Cape gannets *Morus capensis*, 1983–2005. *African Journal of Marine Science* 31: 31-54.



APPENDICES

Appendix I – Lessons learned during the study

I have spent the last 2 years analyzing the data used in this study and I also conducted work in the Stony Point and Dyer Island Penguin colony for 10 years while working at CapeNature. During the capturing of the data used in this study I learned lessons about data collection and capturing that I would like to share that can perhaps assist managers at African penguin colonies. Data are captured in various formats and different ways, which make it difficult to analyze and compare it.

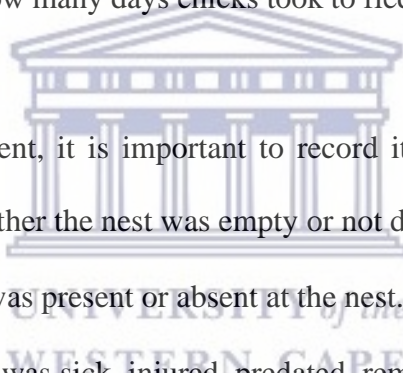


By making use of the breeding success access database and chick condition access database (software developed by Barbara Barham) this will ensure that data are captured and stored in a standard format. Access databases forces a user to complete all the relevant fields and thus ensure consistency. If the breeding success data are captured in the database, it simplifies the completion of the Mayfield process and limits errors. The chick condition database is a very useful tool for field staff to confirm if a chick is in poor condition, the database automatically captures the info on a graph to visually display the condition.

Each year before incubation starts, the marked breeding success nests of the previous year should be evaluated. Decide how many nests you want to include in breeding success monitoring and make sure that all the nest types are included in the monitoring. Nests that have not been active in the previous two seasons should be removed from the list and replaced with similar new nest types.

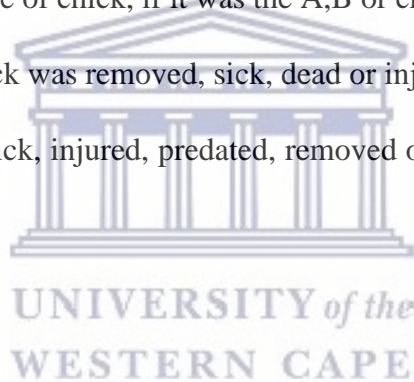
The following should be noted during breeding success monitoring:

- When adding new nests to the breeding success sample, make sure that the nest number is not a duplicate of previous numbers.
- Record the nest type, GPS location and date that the new nest number was added to the sample.
- Ensure that the nest numbering is clearly visible, this will make monitoring easier.
- Breeding success monitoring should start during incubation, the first date with eggs is crucial, otherwise it is difficult to determine the exact time spent on incubation.
- Breeding success monitoring should be done every 7 – 10 days until chicks have left the nest, to determine how many days chicks took to fledge the nest and if they fledged successfully.
- If the nest had no content, it is important to record it as such, otherwise it can be confusing if unsure whether the nest was empty or not done.
- Record whether adults was present or absent at the nest.
- Record whether a chick was sick, injured, predated, removed or dead and the cause of death if possible, this is important to determine why the chicks failed to fledged the nest.
- Each adult at each nest must be checked for a transponder at every visit so that individuals can be followed, this provides information about adult survival and the individual differences in parenting.
- The breeding success data recorded should be captured in the breeding success database upon completion of the collection of the data in field. The database will assist in highlighting mistakes made during the collection of the data.



The following should be kept in mind during chick condition measurements:

- Chick condition is done randomly in colonies, but the focus should be on breeding success nests as this will aid in further research.
- Try to measure chicks from various nest types, to be able to compare chick condition between the various nest types.
- Chick condition measurements should be combined with other research such as transpondering to limit the disturbance and handling of birds.
- Record the nest number of chicks measured if it is a breeding success nest in order to compare chick condition and breeding success data.
- Record the nest type, age of chick, if it was the A,B or crèche chick.
- Record whether the chick was removed, sick, dead or injured.
- Record if a chick was sick, injured, predated, removed or dead and the cause of death if possible.



Appendix II – African Journal of Marine Science – Instruction for authors

Submission and editorial policy

Submissions should be made online at the *African Journal of Marine Science* ScholarOne manuscripts site (<http://mc.manuscriptcentral.com/tams>). New users should first create an account. Once a user is logged onto the site, submissions should be made via the Author Centre. Should you have difficulty submitting material online, please notify the Editor-in-Chief, Sheldon Dudley, at sheldond@daff.gov.za.

In a cover letter, the author is encouraged to suggest the names and contact addresses (including e-mail addresses) of three appropriate referees who have not been associated with the research being submitted, although the Editors will not be bound by such suggestions. Furthermore, the author *must* confirm in the letter that the work is original and is not currently under consideration for publication elsewhere. Contributions must conform to the principles outlined in the document titled **Ethical Considerations in Research Publication** available from the Journal's **Instructions for Authors** webpage.* Submission of a manuscript implies the transfer of the copyright for the accepted article to the publisher and all those media that the publisher considers suitable for the dissemination of the work. However, the author retains the right to disseminate his/her own work.

Maximum lengths of contributions should be 2 500 words for a Short Communication and 7 500 words for a full Research Paper, although a Review Paper of up to 12 000 words will be considered. Word counts include references but exclude tables. Short Communications are used to describe smaller pieces of completed work and should have a combined maximum of four

figures and tables. Supplementary Information, such as questionnaires and ancillary data, can be included but will be published online only.

The Journal uses single-blind peer review, where the identity of the reviewers is unknown to the author(s).

Text

- The entire manuscript should be double-spaced—though greater spacing may be used where helpful (particularly around equations and formulas).
- Lines should be numbered continuously.
- All pages should be numbered with Arabic numbers.
- Each of the following sections should be started on a new page:
 - title (informative but brief), authors' names and affiliations (with city and country), and e-mail address of the corresponding author;
 - abstract, followed by 5 to 8 keywords or phrases that do not appear in the title and that are obtained from the whole article;
 - main text;
 - references list;
 - tables;
 - legends for figures;
 - appendices (which will appear at the end of the article); Supplementary Information (which will appear online only), should be provided as a separate document.

The main text should follow the order: Introduction, Materials and methods, Results, Discussion, Acknowledgements and References. Review Papers would typically exclude the sections Materials and methods and Results, and might include Conclusions.

- Headings and subheadings should not be numbered. Three levels of headings should be sufficient and distinguished as follows: main heading – **bold**; level 2 – ***bold italics***; level 3 – *italics*.
- New paragraphs should be clearly identified.
- Only those words to be printed in italics should be shown as so.
- All measurements (linear, mass, time, etc.) should be given in numerals (not words) in the metric system. When other units of measure are preferred, authors should include metric equivalents. Metric units used and their abbreviations should be those approved by ISO (International Standards Organization), e.g. 25 mm, 16 mg ml⁻¹.
- A document entitled **Presentation of Mathematical and Statistical Data** is available from the Journal's Instructions for Authors webpage.*
- Numbers in the text are to be spelled out if smaller than 10, but a series of numbers (including numbers smaller and larger than 10) should all be listed in numerals. In a sentence overloaded with numbers it is permissible to give certain categories in numerals and others in words. Do not begin a sentence with a numeral.
- Use of footnotes is discouraged, but if necessary they must be numbered consecutively in the text and typed under a horizontal line at the foot of the relevant page.

Abstract

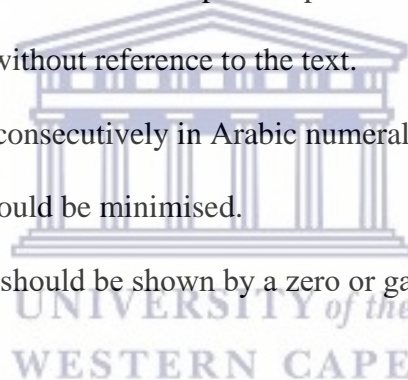
1. Each manuscript must have an abstract, the length of which should not exceed 200 words or 3% of the paper, whichever is the lesser.
2. Subdivision into paragraphs and inclusion of references to literature are not permitted.
3. The abstract should summarise the contents and conclusions of the paper, point to new information contained therein, and indicate the relevance of the work.

Acknowledgements

This section is to be kept brief and only special help acknowledged, as well as funders of the research.

Tables

1. Tables should be carefully constructed so that the data presented may be easily understood; do not overload a table with information.
2. In constructing tables, the size of the printed publication (210 x 275 mm) should be kept in mind.
3. Each table should be provided with a descriptive caption which, together with the column headings, makes it intelligible without reference to the text.
4. Tables should be numbered consecutively in Arabic numerals.
5. Use of footnotes to tables should be minimised.
6. Magnitudes known to be nil should be shown by a zero or gap, and 'no data' by an en-dash or in words.
7. Decimal fractions should be preceded by a zero, and columns of figures should align on the decimal marker. Integers are to be aligned on the least-significant digit. A space should be used to separate thousands (groups of three digits), but such spacing does not apply to years.
8. Tables and figures do not normally duplicate one another. Select the most appropriate presentation, e.g. graphs for trends.
9. Each table should be referred to in sequence in the text and described.



Figures

1. All illustrations, whether black and white drawings, graphs, photographs (colour or monochrome) or charts, are to be designated as figures. Colour will be used only when essential.
2. Figures must be numbered consecutively in Arabic numerals and mentioned by number in sequence in the text.
3. A legend and key (if required) should be provided for each figure, which, together with the illustration, should make the whole intelligible without reference to the text.
4. Small illustrations may be grouped together on a page, with the parts then identified by small letters, e.g. Figure 1a, 1b. The legend should be written to correspond to these.
5. Figures are to be prepared to fit a maximum width of either 84 mm (single column) or 176 mm (double column) on the printed page. The size, line thickness and spacing of the lettering, lines and data points should take into account the final size of the illustration. For graphs and diagrams, lines should be 0.5 point with lettering in 9-point Arial.
6. Illustrations where the size of the object shown is important should have a metric bar-scale drawn on them, or else the actual size may be mentioned in the legend.
7. Care should be taken so that figures are not overcrowded with information. Alternately, information that can easily be depicted in a single figure should not be given in several.
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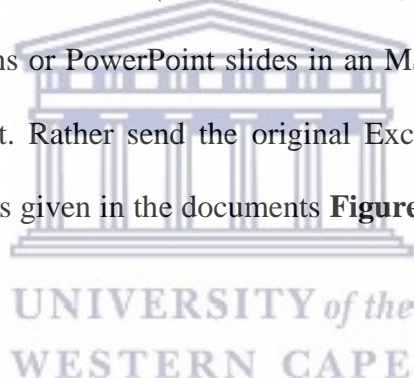
printed page size (210 x 275 mm). Costs of redrawing figures may be charged. Please refer to the document titled

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For digital photographs or scanned images the resolution should be at least 300 dpi for colour or greyscale artwork, and a minimum of 600 dpi for black line drawings. These can be saved (in order of preference) in PSD, JPEG, PDF or EPS format.

Graphs, charts or maps should be exported to AI, PDF, EMF, SVG, WMF or EPS format. In this way the vector format is preserved, allowing for minor changes to be made by the publisher; where necessary MS Office files (Word, PowerPoint, Excel) are also acceptable, but DO NOT EMBED Excel graphs or PowerPoint slides in an MS Word document, which can render them impossible to edit. Rather send the original Excel or PowerPoint files. More detailed technical information is given in the documents **Figure Guidelines for Authors** and

Figure FAQs.*



Species nomenclature

First use of a species name in the title, abstract, and main text should include both the common name (where available) and scientific name. In addition, for works with taxonomic relevance, the describing authority and date of authorship may also be included with first mention of the scientific name in the text, and a comma should separate the authority from the date. The author's citation of the species name should follow the rules of either the International Code of Zoological Nomenclature or the International Code of Nomenclature for algae, fungi, and plants, as appropriate. For zoological species, note the correct use of parentheses when citing the naming authority and date: without parentheses when the current accepted genus and species name is as given by the original naming author, e.g. *Dotilla fenestrata* Hilgendorf,

1869; or, within parentheses when the current accepted scientific name differs from that originally given, e.g. *Scylla serrata* (Forsskål, 1775). For botanical species, where there is a new combination of genus and specific name, both the author(s) of the original genus placement and those of the new combination are given, with the former in parentheses. In the remainder of the manuscript, just one name (scientific or common) should be used, but preferably the scientific name. A genus name can be abbreviated to a single letter (e.g. *P. rupestris*) other than (a) at the beginning of a sentence, where the full name should be used, or (b) where there are multiple genera with the same first letter, in which case the first two letters may be used.

References

1. Reference to literature cited in text could be as follows: ‘Griffiths (2000) showed that...’ or ‘...intense plankton production (Carr 2002)’. Other examples: Crawford (2001, 2003); (Crawford 1981a, 1981b; Hampton 1987).
2. An unpublished book or article that has been accepted for publication can be listed in the references followed by the notation ‘in press’. However, only those manuscripts that are in page-proof stage or for which there is an acceptance letter can be considered in press. As much information as possible is to be given about the intended manner of publication, e.g. name of journal and issue no. If an article is in preparation, or submitted but yet not accepted, state the name and affiliation of the author of the material followed by the notation ‘unpublished data’ in the text and do not include it in the references list. Reference to ‘pers. comm.’ is allowed.
3. In-text citations of works with two authors should be given as, e.g. Barange and Pillar (1992); works with more than two authors should be given as the first author followed by et al., e.g. Payne et al. (1982).

4. A direct quotation from a reference should list the page quoted and be enclosed in quotation marks. Spelling, punctuation and wording must match the original; a mistake in the original may be pointed out by inserting [sic].
5. Works quoted in the text but not actually seen should be given in the form e.g. Ratcliffe (1991) as cited by Dallas and Day (1993). Such literature (in this case, Ratcliffe 1991) should not be included in the references list.
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7. The list of references at the end should be provided in alphabetical order of the first authors. Within a group of publications with the same first author, the sequence is as follows: (i) single-author publications, listed chronologically; (ii) two-author publications, listed alphabetically on the second author and then chronologically; and (iii) publications with two or more co-authors, listed chronologically only.
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10. Journal titles must be provided in full.
11. Works quoted in a language different from that of the original publication are to be identified as such in parentheses at the end of the reference, e.g. (translated from Russian). Titles of works written in non-Roman characters are to be transliterated and the fact noted by appending e.g. (in Japanese) or (in Russian, with English abstract).

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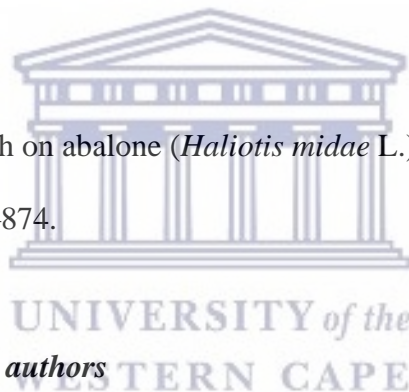
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Journal article, more than two authors

Ellender BR, Weyl OLF, Shanyengange MK, Cowley PD. 2008. Juvenile population dynamics of *Oreochromis mossambicus* in an intermittently open estuary at the limit of its natural distribution. *African Zoology* 43: 277–283.

Note: Issue numbers are omitted from citations.

Abstract as original source [not to be encouraged]

Botha CEJ, Liu L, Cross RHM. 2005. Functionality within plasmodesmata: roles for callose, actin and myosin? [Abstract]. *South African Journal of Botany* 71: 261.

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Book

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Note: '(2nd edn)' is not italicised.

Edited book

Huntley BJ, Walker BH (eds). 1982. *Ecology of tropical savannas*. Berlin: Springer-Verlag.

Chapter in a book

de Villiers C, Hodgson A, Forbes AT. 1999. Studies on estuarine macrobenthos. In: Allanson BR, Baird D (eds), *Estuaries of South Africa*. Cambridge: Cambridge University Press. pp 167–207.

Non-English book

Makatsch W. 1974. *Die eier der vögel Europas*, vol. 1. Berlin: Neumann.

Newspaper article, no author

Anon. 2002, January 19. Why target the good guys, Mr Moosa? *The Herald*. p 4.

Booth A. 2005. South African monkfish (*Lophius vomerinus*) stock assessment. Report No. WG/05/04/D:A:07. Marine and Coastal Management, Cape Town.

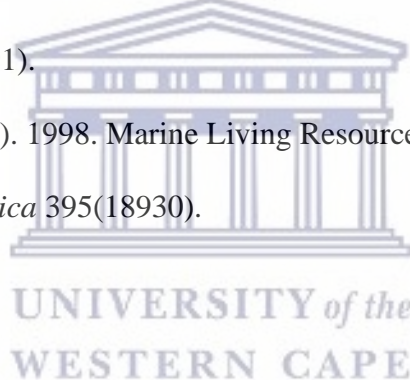
Contract research document (published)

Whitfield AK, Bate GC (eds) . 2007. *A review of information on temporarily open/closed estuaries in the warm and cool temperate biogeographic regions of South Africa, with particular emphasis on the influence of river flow on these systems*. WRC Report No. 1581/1/07. Pretoria: Water Research Commission.

Government legislation (upper case used for formal documents)

DEAT (Department of Environmental Affairs and Tourism). 2006. Publication of draft policies for the allocation and management of medium-term small-scale commercial fishing rights and for the allocation and management of medium-term subsistence fishery rights. *Government Gazette, South Africa* 497(29391).

RSA (Republic of South Africa). 1998. Marine Living Resources Act (Act No. 18 of 1998). *Government Gazette, South Africa* 395(18930).



Series

Govender A. 2000. Garrick (*Lichia amia*). In: Mann BQ (ed.), *Southern African marine linefish status reports. Special Publication No. 7*. Durban: Oceanographic Research Institute. pp 16–17.

McKenzie CL, Burrell VG, Rosenfield A, Hobart WL. 1997. The history, present condition, and future of the molluscan fisheries of North and Central America and Europe. Vol. 1: Atlantic and Gulf Coasts. *NOAA Technical Report* 127.

Rolando CA, Hitchins M, Olivier S. 2006. Methods to improve late season planting of *Pinus patula*. *ICFR Bulletin Series* No. 08/2006. Pietermaritzburg: Institute for Commercial Forestry Research.

Dissertation/thesis

Vorwerk PD. 2006. A preliminary examination of selected biological links between four Eastern Cape estuaries and the inshore marine environment. PhD thesis, Rhodes University, South Africa.

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Gibbons M. 2006. Engagement as a core value in a Mode 2 society. Paper presented at the CHEHEQC/JET-CHESP Conference on Community Engagement in Higher Education, Cape Town, 3–5 September 2006.

Conference/workshop proceedings

Tibbits WN, Boomsma DB, Jarvis S. 1997. Distribution, biology, genetics and improvement programmes for *Eucalyptus globulus* and *E. nitens* around the world. In: White T, Huber D, Powell G (eds), *Proceedings of the 24th Biennial Southern Tree Improvement Conference, 9–12 June, Orlando, Florida*. Orlando: Southern Tree Improvement Committee. pp 1–15.

Unpublished report

Fielding PJ. 1997. Stock assessment and fisheries management of the Natal rock lobster *Panulirus homarus*. In: Report No. 140. Durban: Oceanographic Research Institute. pp 13–17.

Geldenhuis CJ. 1975. Stock enumeration and management planning of the woodlands in Kavango. Unpublished report. Saasveld Forestry Research Centre, George.

Whittington PA. 2000. The Cape Town Harbour oil spill – one year after the event. Avian Demography Unit Research Report No. 37. University of Cape Town, Cape Town.

Article in press (accepted for publication)

Wolfaardt AC, Underhill LG, Crawford RJM. In press. Comparison of moult patterns of African penguins *Spheniscus demersus* at Robben and Dassen Islands. *African Journal of Marine Science* 31.

Note:

- Unpublished manuscripts that have either not been submitted for publication or that have been submitted for publication but not yet accepted are to be cited as ‘unpublished data’.
- Provide the doi, where available, for an article in press (see exemplar under ‘electronic medium’ below).

Examples of reference list formats — electronic medium

Atwell A. 2005. The sad state of editing. Available at www.arthuratwell.com/entries/journal290805.html [accessed 20 February 2007].

Carrasco NK, Perissinotto R. 2012. Development of a halotolerant community in the St Lucia Estuary (South Africa) during a hypersaline phase. *PLoS ONE* 7: e29927.

Koné V, Machu E, Penven P, Andersen V, Garçon V, Fréon P, Demarcq H. 2005. Modeling the primary and secondary productions of the southern Benguela upwelling system: a comparative study through two biogeochemical models. *Global Biogeochemical Cycles* 19: GB4021.

Non-standard references

Most types of references that will appear in a manuscript are catered for in the exemplars above. For non-standard references, provide sufficient bibliographic information to allow other researchers to locate the original through their library, bibliographic database, inter-library loan

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Abbreviations within the reference list

Anonymous Anon.

Article Art.

Chapter chap.

Edited by ed.

Multiple editors eds

2nd edition 2nd edn

No date n.d.

Number No.

Page (single) p [used for single-page citations from books/ reports (not journals)]

Page numbers pp (followed by a space and page range)

Supplement Suppl.

Translated by transl.

Volume (book) vol.

Volumes vols



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- The list of references provided at the end of the text must be cited in alphabetic sequence of first authors, e.g. Pauly (1998) will precede Pauly and Torres (1997).
- When more than one publication by the same author is listed, his/her name must be repeated and the listing is chronological.
- When more than one multi-authored work by the same senior author is listed, the listing is alphabetical in terms of the co-authors and chronological where there is more than one work by the same group of authors.

- For multiple works published in the same year by the same author/s, distinguish the references by an ‘a’, ‘b’, etc. following the publication year [see ‘Citation of references within the text’ below].
- Titles of periodicals must be listed in full.
- Works quoted in a language different from that of the original publication are to be identified as such, e.g. (translated from Russian) in parentheses at the end of the reference. The titles of works written in non-Roman characters are to be transliterated and the fact noted by appending (in Japanese) or (in Russian, with English abstract).

Citation of references within the text

- The basic referencing style of literature cited in the text is as follows: Williams (1979) observed..., or ...hectare (Baggio 1997, 1999). A group of references is listed chronologically, e.g. (Wooldridge 1999; Froneman 2001; Brouwer and Griffiths 2004).
- Reference in the text to publications with three or more authors should be given as the senior author et al., e.g. Chong et al. (2003).
- When an author has written more than one work in the same year, use ‘a’, ‘b’, etc. to differentiate between the publications, e.g. 2000a, 2000b. An ‘a’ is appended to the first reference cited in the text, ‘b’ to the second cited, etc.