The effects of anthropogenic disturbance upon African penguin colonies

Rebecca Jane Miller

Department of Biodiversity and Conservation Biology

University of the Western Cape

Private Bag X17, Bellville 7535

South Africa.

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Supervisor: Prof. Gavin W. Maneveldt

Co- supervisors: Dr. Lorien Pichegru, Dr. Richard B. Sherley, Dr. Lauren J. Waller

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Plagiarism declaration

I declare that "The effects of anthropogenic disturbance upon African penguin colonies" is my own work, that it is not submitted for any degree or examination at any other university, and that all sources I have used or quoted have been indicated and acknowledged by complete references.

20th March 2020

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Rebecca Jane Miller **Date**

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Thesis Summary

African penguin (*Spheniscus demersus*) mainland colonies are a popular tourist attraction in the Western Cape of South Africa. The African penguin population is in decline and the species is listed as endangered on the International Union for the Conservation of Nature (IUCN) Red List. This thesis aimed to investigate the impact of ecotourism upon African penguin colonies by comparing two colonies of differing levels of tourist visitation in the Western Cape in 2017. The high visitation colony is a mainland colony where ecotourism activities take place (Stony Point), and the low visitation colony is an island colony where ecotourism does not occur (Robben Island). As well as inter-colony comparisons, nests at the high visitation colony within areas of differing exposure levels were also compared.

Chapter 1 provides a short introduction to ecotourism and human disturbance within penguin colonies. Background information on stress and breeding success research in penguins and why it is important is also provided. This chapter introduces the study species and the study sites in detail.

Chapter 2 looks at the breeding success and chick condition of African penguins in relation to ecotourism. At the high visitation colony, breeding success and chick condition were three times lower than at the low visitation colony. This suggests the possibility of ecotourism having a negative impact upon breeding success and chick condition. There was no significant difference in breeding success and chick condition between nests of differing levels of human exposure within the high visitation colony, though there was a tendency for chicks in the control area to be in poorer condition. These observations may be explained by

other environmental factors such as higher nest density and the associated high levels of parasites, as well as predation by mainland predators.

Chapter 3 investigates the stress levels of chicks at the high and low visitation colonies by analysing urofaecal samples. The chicks were found to be less stressed at the high visitation colony, which may be due to the higher level of constant exposure to humans at the colony leading to an increased tolerance and potential for habituation. Chicks at the low visitation colony may be experiencing higher levels of stress as a result of environmental factors such as food availability. This observation of lower stress levels among chicks at the high visitation colony does suggest that ecotourism is not having a negative impact upon stress, and that the current visitor management practises in place are sufficient.

Chapter 4 discusses the results from Chapters 2 and 3, and suggests that ecotourism is having an impact on African penguin colonies, particularly in terms of breeding success and chick condition. It is difficult to make firm conclusions due to the multitude of other factors that may be influencing the colonies aside from ecotourism. These results should therefore be treated as a pilot, as they highlight the importance of multi-disciplinary studies, and suggest that research in the future should consist of a multi-year study that includes other data such as visitor numbers, food availability, and predation incidences. These studies should also involve other colonies that experience even higher and lower human disturbance rates in order to gain a more in depth look at how exactly ecotourism is affecting the colonies in question.

Chapter 1 – General Introduction

1.1 Introduction

Seabirds are the most threatened group of birds, and of all the seabirds, the orders that are most threatened are penguins (Sphenisciformes) and albatrosses/petrels (Procellariiformes) (Croxall et al. 2012). Penguin species across the world are facing a range of threats, leading to widespread declines in more than half of the 18 species, with 10 species being considered vulnerable or endangered on the International Union for the Conservation of Nature (IUCN) Red List (Boersma et al. 2019; IUCN 2019). The most critical threats facing penguin populations include pollution from oil spills and marine litter, climate change, habitat degradation, competition for prey with fisheries, predation and human disturbance (Dias et al. 2019).

1.2 Human Disturbance

Human disturbance can be defined as any human activity that changes the behaviour or physiology of one or more individuals (Nisbet 2000). Examples of this include scientific research activities and tourism that involves visiting animals within their natural habitats. As the human population continues to increase, these anthropogenic activities are likely to have a greater impact on penguin species, since it is likely that higher volumes of people will take part in ecotourism activities and visit the colonies of threatened and endangered penguin species.

The definition of ecotourism is widely debated, but it can be broadly defined as a form of nature-based tourism that focuses on the natural environment (Weaver 2006). Globally, ecotourism has grown significantly in recent years (Sharpley 2006) with an estimated annual

growth rate of 10-15% in the 21st century (Erdoğan 2017). Penguin colonies in particular are popular ecotourism destinations with people travelling across the world to see different penguin species in their natural habitat. This is because of the anthropomorphic stance and charisma of penguins and the possibility of close-up encounters (Ellenberg 2017; Ropert-Coudert et al. 2019), the latter being a key component of the visitor experience (Curtin 2005). Ecotourism around penguin colonies takes a number of different forms, including viewing the penguins from observation hides (Ratz & Thompson 1999) and boardwalks (Lewis et al. 2012), to kayaking trips (e.g. Kayak Cape Town 2019). African penguin (*Spheniscus demersus*) colonies are popular tourist destinations in the Western Cape of South Africa, with two easily accessible mainland colonies in close proximity of Cape Town, namely the Boulders Beach colony in Simon's Town, and the Stony Point colony in Betty's Bay (Fig. 1.1).

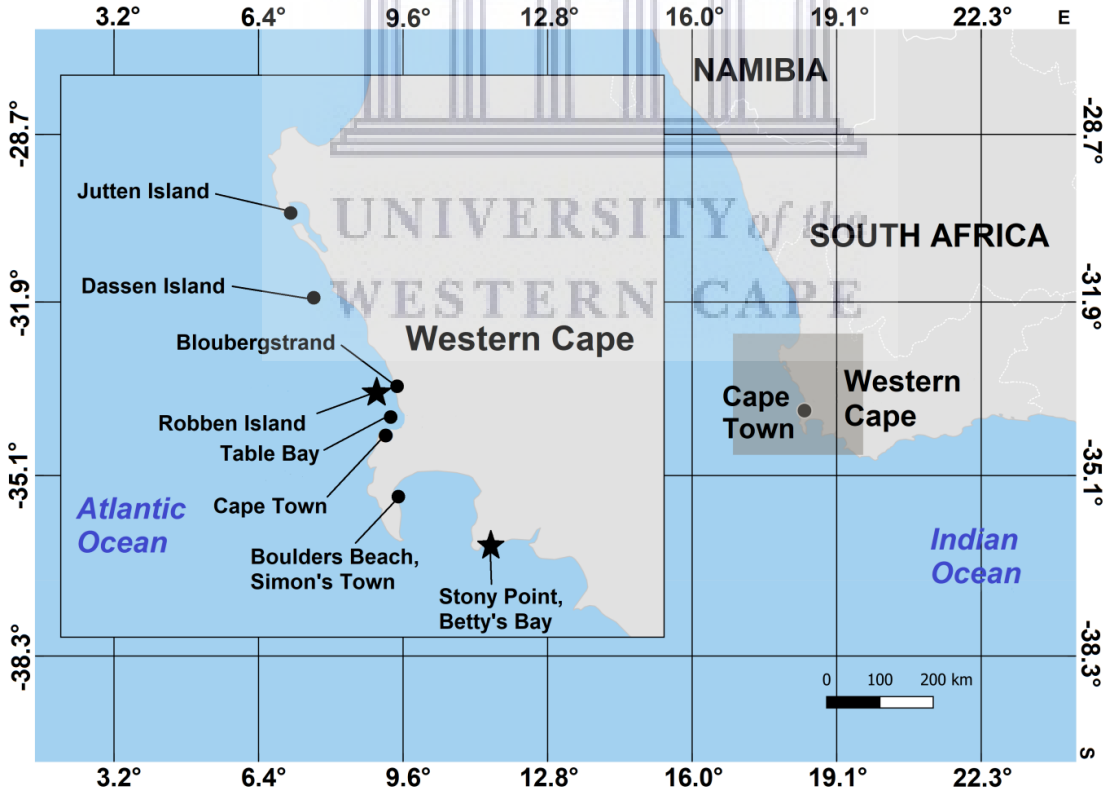

Figure 1.1. Map of South Africa showing the locations (stars) of the two penguin colony study sites involved in this study (Robben Island and Stony Point) as well as another popular colony in terms of ecotourism (Boulders Beach) in the Western Cape, and other localities mentioned throughout the thesis.

Chapter 1 – General Introduction

The presence of humans around and within penguin colonies can have a direct impact in the form of vehicle-related mortalities of birds due to the increasing traffic surrounding the colony, but also less direct disturbance that may have deleterious long-term effects impacting their breeding success and survival (Seddon & Ellenberg 2008; Ellenberg 2017). There are, however, advantages to this form of tourism as it brings a number of benefits to the general public and the conservation of wildlife, through contributions to the local economy and public environmental education (Yorio et al. 2001; van Zyl 2014). The income generated can also partially contribute towards conservation efforts. For example, South African National Parks (SANParks), the managing authority of the Simon's Town Boulders Beach penguin colony in Cape Town, South Africa, raises more than 80% of its total organisation's finances through tourism (Biggs et al. 2014). Boulders Beach was the fifth most popular tourist attraction in Cape Town in 2017, attracting 930,000 visitors, most of which were international tourists (van Zyl & Kinghorn 2018). A recent study estimated the expenditure by tourists and residents associated with the Boulders Beach penguin colony to be approximately R311 million (US$22 million) per annum (van Zyl & Kinghorn 2018). This revenue has not only supported the organisation and the conservation of their national parks, but has also contributed towards employment and wider social development goals (Emerton et al. 2006). A study based on IUCN Red List data estimated that 26,040 African penguins (64% of the global population at the time) are protected through tourism in terms of contributions of revenue to the protection of their habitats (Steven et al. 2013) which highlights one of the positive effects that tourism can have upon an endangered species. However, despite these economic and conservation benefits, it is important that the impact of ecotourism and the associated anthropogenic interactions with threatened and endangered populations are understood and properly managed to avoid any long-term negative consequences.

Chapter 1 – General Introduction

The impact of human disturbance, including ecotourism, has been studied in a number of penguin species. Some species have shown potential for habituation to human disturbance, with birds breeding in areas of frequent human disturbance showing a significantly lower stress response to the presence of humans in comparison to those in areas with low rates of disturbance. Examples include the African penguin (van Heezik & Seddon 1990; Pichegru et al. 2016), gentoo penguin (*Pygoscelis papua)* (Holmes et al. 2006), king penguin (*Aptenodytes patagonicus)* (Viblanc et al. 2012), and Magellanic penguin (*Spheniscus magellanicus)* (Fowler 1999; Walker et al. 2006; Villanueva et al. 2012). In contrast, Humboldt penguins (*Spheniscus humboldti)* are very sensitive to human presence, exhibiting high heart rates with ~30 minute recovery time, as well as reduced breeding success in frequently visited sites (Ellenberg et al. 2006). Yellow-eyed penguins (*Megadyptes antipodes)* can also be negatively impacted by frequent human disturbance, with individuals exhibiting higher stress responses and lower breeding success in comparison to those in areas that are rarely visited (Ellenberg et al. 2007). These contrasting findings between different penguin species highlight the need for species-specific management, even in species that are closely related. Differences in human tolerance have also been shown within the same species at differing colonies, for example in African penguins (Pichegru et al. 2016) and Humboldt penguins (Ellenberg et al. 2006) so in addition to considering individual species, management techniques should also be specific to each colony in order to address these differences and ensure that effective measures are implemented at each colony.

As so many penguin species are declining, understanding the impact of human disturbance such as ecotourism on the stress levels, productivity and body condition of penguins at different colonies, is increasingly valuable for colony managers. This information can inform

and enable effective management of human presence within these colonies and may therefore reduce any negative impacts on their population numbers.

1.3 Studying stress in penguins

Stress can be defined as the physiological response of an individual when faced with a perceived threat to homeostasis (Hulsman et al. 2010). When an individual faces a stressor, a stress response is elicited. The stress response involves the activation of the hypothalamic-pituitary-adrenal (HPA) axis and the secretion of cortisol or corticosterone from the adrenal gland (Cockrem 2007). This results in behavioural and physiological changes that enable the individual to cope with the stressor (Romero 2004; Palme et al. 2005). In birds, the hormone released is corticosterone, which results in changes such as an increase in blood glucose levels, behavioural changes and other actions that help the individual to respond to a stressor (Sapolsky et al. 2000). Measuring the levels of this hormone can determine to what degree an individual is experiencing stress (Cockrem 2007). Stress is known to have an impact upon reproduction, behaviour and immune systems (Touma & Palme 2005) and repeated exposure to stressors can lead to long term elevated levels of stress which is known as chronic stress (Geffroy et al. 2017). Animals experiencing chronic stress can show impaired levels of growth and lower survival in general (McEwen 1998). Measuring stress hormones as a proxy of stress is therefore an important tool to investigate different factors affecting penguins such as human visitation, and the results of such studies can provide valuable insights about the health of individuals and populations.

Stress can be measured in a number of ways including behavioural observations and the analysis of biological samples, which involves methods that are both invasive and non-invasive. Biological sampling methods include the measurement of glucocorticoid

metabolites in blood, saliva, feathers, hair, urine and faecal samples (Sheriff et al. 2011). Blood sampling is considered an invasive method due to the need to handle and restrain the individuals for a period of time during sample collection. This can also have an impact upon the levels of the hormone being recorded, as the handling and restraint elicits a stress response, and levels of glucocorticoid in blood can increase significantly within 2–5 minutes, making it difficult to obtain baseline stress levels using this method (Sheriff et al. 2011). Measuring faecal glucocorticoid metabolites is an increasingly utilised method among ecologists as it is considered a non-invasive method (Romero 2004). This method has been used in studies of stress in a number of species both in the wild and in captivity, including the impact of tourist visitation upon orangutans (*Pongo pygmaeus morio*) (Muehlenbein et al. 2012) and gentoo penguins (Lynch et al. 2019), and the effects of weather and visitors on captive African penguins (Ozella et al. 2017).

Ecotourism sites often have guidelines for visitor approach distances that are based on behavioural responses; however, non-visible physiological stress responses due to human proximity may be increasing energy demands that are not reflected in the behaviours displayed (Tarlow & Blumstein 2007; Ellenberg 2017). This highlights the importance of considering physiological responses in addition to behavioural responses in studies of human disturbance and stress.

1.4 Studying breeding success in penguins

Breeding success is a critical measure of productivity that influences population dynamics and the conservation status of a species (Wolfaardt et al. 2008). Measuring breeding success of penguin colonies involves monitoring nests throughout the breeding season, recording the contents and thereby tracking the survival of chicks and eggs. Factors influencing the

breeding success of penguins includes nest type (Sherley et al. 2012; Pichegru 2013), exposure to oil pollution (Barham et al. 2007; Wolfaardt et al. 2008), predation (Pichegru 2013), human disturbance within colonies (Hockey & Hallinan 1981; Giese 1996) and food type and availability (Crawford et al. 2006; Durant et al. 2010; Sherley et al. 2013).

Human disturbance has been shown to impact the breeding success of a number of penguin species. In a mixed colony of Magellanic and Humboldt penguins in southern Chile, the occurrence of unregulated tourism activities within the colony has been attributed to a high proportion of collapsed nests (Simeone & Schattler 1998). Adélie penguin (*Pygoscelis adeliae*) and Humboldt penguin colonies that are subjected to recreational visits have been shown to have lower hatching success and survival than undisturbed colonies (Giese 1996; Ellenberg et al. 2006). The presence of humans in breeding colonies may disturb adults that are tending to eggs or chicks, causing them to temporarily or permanently abandon their nest which can facilitate predation as the chicks and eggs are left to fend for themselves. This has been observed in African penguin eggs being predated on by kelp gulls (*Larus dominicanus*) due to disturbance associated with human passage through a colony (Hockey & Hallinan 1981).

1.5 Study species: African penguin *Spheniscus demersus*

The African penguin is the only penguin species that breeds on the African continent, and is found along the southwestern coast of Africa, breeding at 28 localities in South Africa and in Namibia (BirdLife International 2018). African penguins forage primarily on small pelagic fish such as sardine (*Sardinops sagax*) and anchovy (*Engraulis encrasicolus*) (Crawford et al. 2011). They are inshore foragers, and are restricted to a foraging range of 20-40 km during

the breeding season when they must return to the colony regularly to feed their chicks (Pichegru et al. 2009).

African penguins breed all year round, with peaks varying between locations (Crawford et al. 2013). In the south west of their range, egg laying peaks between May and July (Crawford et al. 2013). The average age at which they begin to breed is between 4 and 6 years of age (Whittington et al. 2005). The clutch tends to consist of two eggs (Crawford et al. 2000) that are laid at an interval of around 3 days (Williams & Cooper 1984). Incubation lasts between 38 and 41 days and is carried out by both parents (Williams & Cooper 1984). After hatching, chicks are attended to by their parents for between 26 and 30 days, after which they are left mostly unguarded, sometimes forming crèches with other chicks (Seddon & van Heezik 1991).

Over the past century the African penguin population has undergone a severe decline, resulting in the species being uplisted from Vulnerable to Endangered status on the IUCN Red List in 2010 (BirdLife International 2018). Approximately 35,000 pairs were lost over the course of 8 years, from 2001-2009 (Crawford et al. 2011) and the population is continuing to decline (BirdLife International 2018). Data from 2015 estimates that there are around 25,000 breeding pairs left in the wild, with around 5,800 of those in Namibia and 19,300 in South Africa (BirdLife International 2018). More recent estimates for South Africa in 2019 have indicated there are only 13,000 breeding pairs left (Department of Forestry and Fisheries, unpublished data). In 2019, the IUCN Species Survival Commission Penguin Specialist Group identified the African penguin as one of the three penguin species in most critical need of conservation action alongside the yellow-eyed penguin and Galápagos penguin (*Spheniscus mendiculus*) (Boersma et al. 2019).

Chapter 1 – General Introduction

Historically, African penguins were subjected to human disturbance through egg collection for human consumption and habitat alteration by guano scraping. These were identified as the main causes of the population decline in the first half of the 20th century, though these practises have largely ceased (Crawford et al. 1995; Underhill et al. 2006). More recently, the most critical threat is reduced prey availability (Crawford et al. 2011; Boersma et al. 2019) due to a combination of environmental changes, some of which are driven by climate change, and competition with fisheries (Sherley et al. 2017). Their main prey items, sardine and anchovy, are exploited by commercial fisheries (Durant et al. 2010). Other threats they currently face include predation by Cape fur seals (*Arctocephalus pusillus pusillus*) (Boersma et al. 2019), land-based predators such as caracal (*Caracal caracal*), leopard (*Panthera pardus*), domestic dog (*Canis lupus familiaris*) and cape grey mongoose (*Galerella pulverulenta*) (Vanstreels et al. 2019), and pollution associated with oil spills (Boersma et al. 2019).

In 2010, a stakeholder workshop was held to identify threats and required mitigation measures that were subsequently used to draft the African Penguin Biodiversity Management Plan. Gazetted in 2013, the main goals were to halt the decline of the population within two years of the publication of the plan; increase the growth in the number of breeding pairs in the wild within five years, and to have the species removed from the IUCN threatened categories. Sections of the Biodiversity Management Plan focus on the impacts of anthropogenic activity, outlining the necessary actions to minimise the disturbance particularly at mainland colonies where visitor numbers can be more than 1,000 per day (Lewis et al. 2012). Additionally, the Plan recommends the development and implementation of guidelines to reduce the impact of these disturbances (Department of Environmental Affairs 2013).

1.6 Study sites

The present study took place in the Western Cape of South Africa, at one mainland colony (Stony Point) and one island colony (Robben Island), that contrast in their levels of human visitation (Fig. 1.1).

1.6.1 Stony Point

The Stony Point African penguin colony (34.3741° S, 18.8917° E) (Fig.1.2) is a mainland colony located in Betty's Bay, a small town on the south west coast of the Western Cape Province. It is approximately 90km from Cape Town. African penguins began to colonise the area in the 1980s, with a rapid increase of breeding pairs in the 1990s (Underhill et al. 2006). It is one of the largest breeding colonies in South Africa in terms of the number of breeding pairs, with 1,705 breeding pairs recorded in 2019 (CapeNature, unpublished data). Stony Point is located adjacent to a residential area. It is also a popular ecotourism destination, managed by CapeNature, and between the years 2009-2018 saw an average of 75,000 visitors per year (CapeNature, unpublished data). Visitors are able to get close to the penguins and their nests via a fenced boardwalk that runs parallel to the coast and below most of the nest sites. There is a portion of the colony where access is prohibited to visitors. In addition to the residential and tourism related human presence at Stony Point, CapeNature colony staff enter the colony for management purposes approximately every 2-3 days, and for monitoring and data collection every 7-9 days (C Hugo pers. comm., CapeNature).

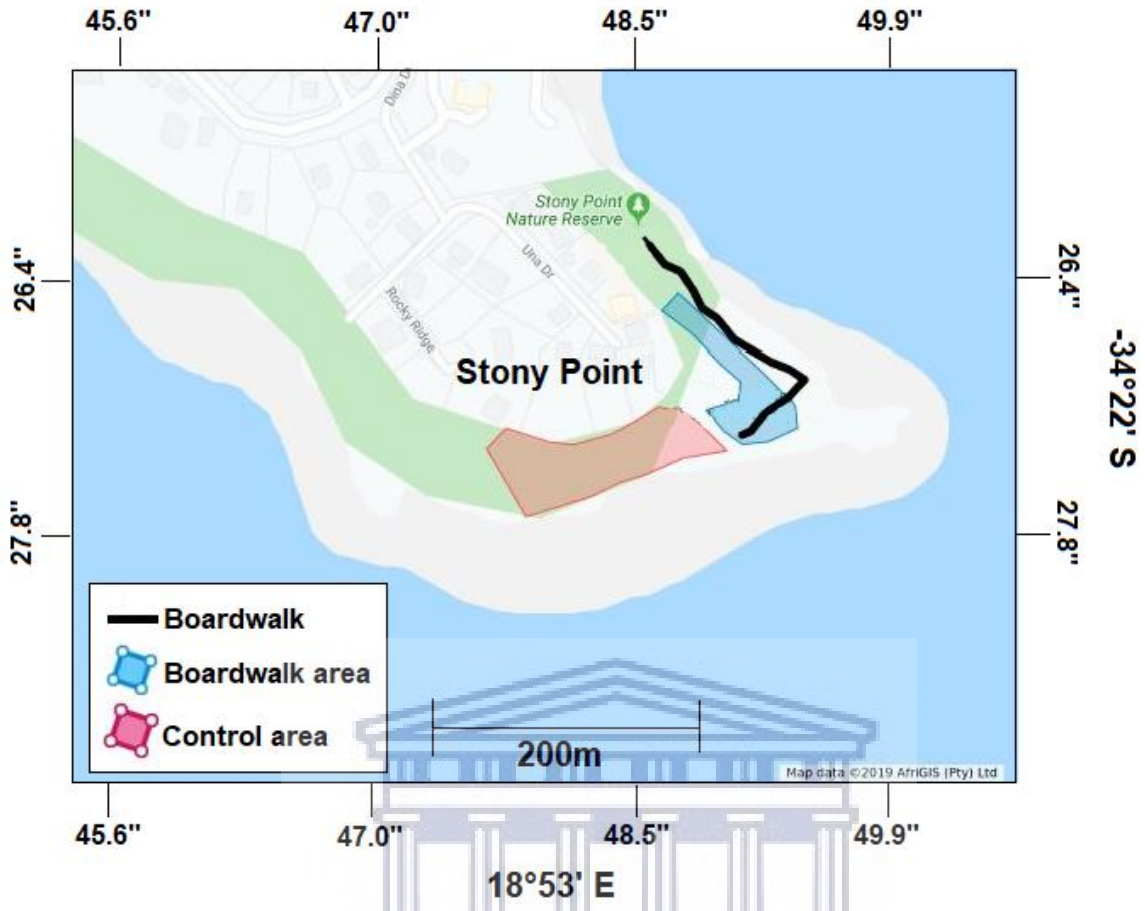

Figure 1.2. Map of the Stony Point penguin colony in Betty's Bay. Both the control and boardwalk nest areas are highlighted, as well as the boardwalk itself.

1.6.2 Robben Island

The Robben Island colony (33.8076° S, 18.3712° E) (Fig. 1.3) is located in Table Bay, around 7km west of Bloubergstrand on the West Coast. It was recolonised by African penguins in the 1980s after 180 years of absence (Crawford et al. 2006), around the same time as Stony Point was colonised. The colony experienced a rapid population increase up to 2004, with a maximum of 8,524 pairs (Underhill et al. 2006). However, 15 years later in 2019 only 1,216 pairs were recorded (Department of Environment, Forestry and Fisheries, unpublished data). Similarly to Stony Point, Robben Island is a residential area and a popular tourist destination, where residents and tourists may encounter commuting penguins as they travel between their nests and the ocean to feed. There were over 370,000 visitors to the

island reported for the 2016/17 tourism reporting period (July - June) and more than 300,000 over the 2017/18 period (Cape Town Tourism, 2017, 2018). However, tourism on Robben Island is centred on visiting the former maximum security prison and other historical landmarks as opposed to viewing the penguins, and visitors do not necessarily come across any penguins whilst touring the island. The penguin breeding areas are strictly prohibited to visitors. During the breeding season, researchers enter the breeding areas for management purposes every 2-3 days, and for monitoring and data collection every 4-7 days (Sherley et al. 2012; Sherley et al. 2018). Due to the lack of visitor presence in the breeding areas, the penguins at this colony are considered to be exposed to a lower level of human visitation in comparison to the penguins at Stony Point.

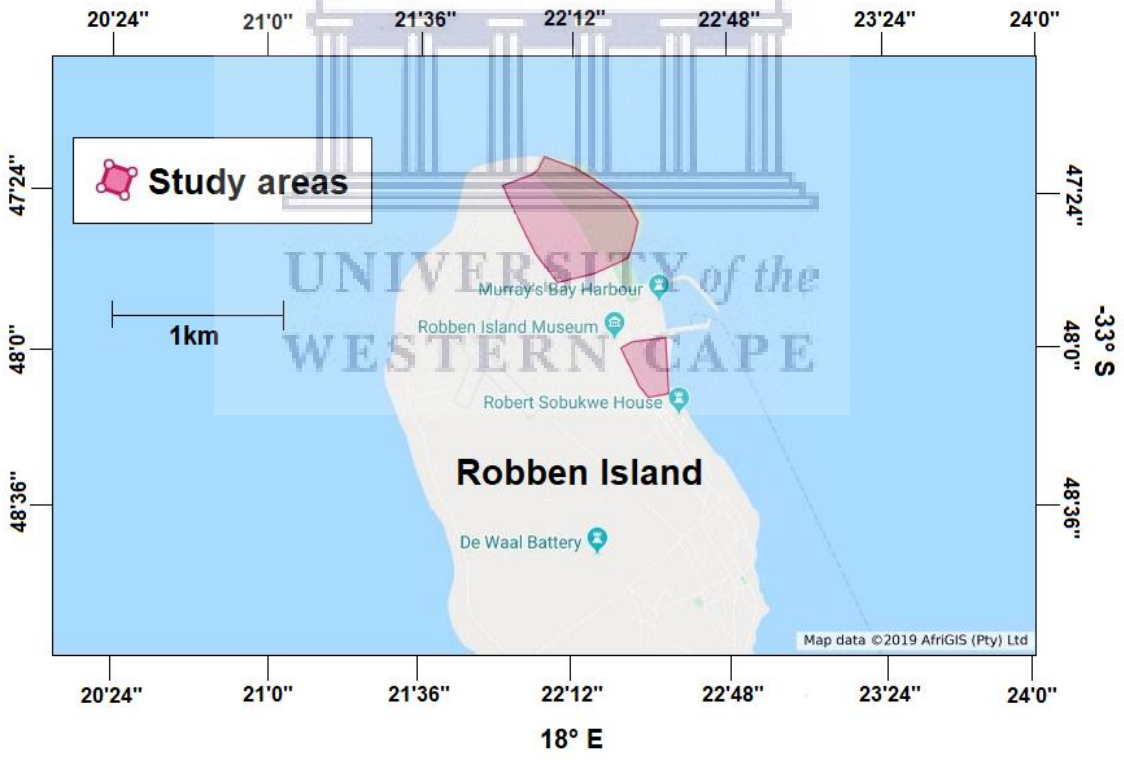

Figure 1.3. Map of Robben Island with study areas highlighted, as well as tourism landmarks.

1.7 Study aims and rationale

The aim of this thesis was to assess the effects of anthropogenic disturbance on African penguins by comparing stress levels, breeding success and chick condition at a South African mainland colony (Stony Point) that experiences high ecotourism visitation numbers, and at an island colony (Robben Island) where human visitation levels are lower and ecotourism does not occur. Breeding success, chick condition and stress levels were also compared within the high visitation colony, Stony Point, in nests that are highly exposed to visitors along the visitor boardwalk and in nests in a control area that is not accessible to tourists.

This study aimed specifically to: (1) evaluate the differences in breeding success between two colonies in the Western Cape exposed to differing levels of human visitation; (2) evaluate the differences in chick condition between two colonies of differing levels of human visitation; (3) compare chick condition and (4) breeding success between nests varying in their proximity to a visitor boardwalk within the high visitation colony; (5) evaluate the differences in faecal glucocorticoid metabolite (FGM) levels of African penguin chicks between the two colonies of differing levels of human visitation; and (6) compare FGM levels between nests varying in their proximity to a visitor boardwalk within the high visitation colony.

Chapter 2 – Impact of human disturbance on African penguin breeding success

2.1 Abstract

The African penguin (*Spheniscus demersus*) is listed as Endangered on the International Union for Conservation of Nature (IUCN) Red List following a decline in numbers over the past century. They are a focal species of ecotourism activities in the Western Cape of South Africa, which is a growing industry. It is therefore important to understand the impact that the associated human presence is having upon the populations involved to ensure this endangered species is effectively protected. This study investigated the potential impacts of ecotourism upon the breeding success and chick condition of African penguins at two colonies that differ in their exposure to ecotourism (a mainland colony that is an ecotourism destination and an island colony that is not exposed to ecotourism). A comparison of breeding success and chick condition was also made within the high visitation colony, involving nests along the visitor boardwalk and in a control area. Breeding success and chick condition were higher at the low visitation colony, suggesting that ecotourism may be having a negative impact on the high visitation colony, though there is the possibility that nest density and predation are also contributing factors to these comparatively lower levels. Within the high visitation colony there was little variability in breeding success and chick condition, though chicks in the control area had a tendency to be in poorer condition than those along the visitor boardwalk. Further research including incorporating another colony exposed to frequent human visitation as well as an undisturbed control colony will be useful to investigate the effects of ecotourism across different levels of intensity. It will also be useful to build in environmental data such as food availability and predation in order to make firm conclusions as they may also be affecting breeding success and chick condition.

Chapter 2 – Impact of human disturbance on African penguin breeding success

2.2 Introduction

Ecotourism is growing worldwide (Sharpley 2006) with many tourists seeking out nature-based experiences and close encounters with wildlife (Curtin 2005). These activities can result in a significant source of revenue for the areas in which the destinations are located (e.g. van Zyl & Kinghorn 2018), but there is a growing concern on the impact that the resulting disturbance from humans is having (Shannon et al. 2017; Stronza et al. 2019).

A negative impact ecotourism can have upon seabird populations visited is reducing breeding success (Shannon et al. 2017). These impacts have been studied in a number of different focal ecotourism species. In Adélie penguins (*Pygoscelis adeliae*), hatching success and chick survival was lower at colonies that were exposed to ecotourism (Giese 1996). Osprey (*Pandion haliaetus*) breeding success has been found to be affected by boat traffic associated with ecotourism, as disturbed females flew off the nests, and males reduced the rate of prey provisioning (Monti et al. 2018). Boat traffic has also been suggested to impact wood storks (*Mycteria americana*), with nests within 20m of the boat passage exhibiting an elevated level of nest failure in comparison to nests in other areas of the same colony (Bouton et al. 2005). In African penguins, the approach of visitors to active nests can result in nesting birds temporarily fleeing the nest, leaving the contents open to predators, including kelp gulls (*Larus dominicanus*) (Pichegru 2013). It can also result in the prevention of nest prospecting birds from establishing nests (Hockey & Hallinan 1981). However, the presence of humans does not always have an observable impact. A study on Magellanic penguins (*Spheniscus magellanicus*) has demonstrated breeding success to be similar between colonies that are visited by tourists and those that are not, with a negative impact only being observed during the initial opening up of the colony to tourism (Yorio & Boersma 1992). One of the key principles of ecotourism is that it should be low-impact and contribute towards conservation

(Sharpley 2006), so it is important to monitor the impact it is having upon wild populations and their numbers to ensure it is being managed effectively.

Breeding success is an important parameter that influences population dynamics and the conservation status of African penguins (Wolfaardt et al. 2008; Sherley et al. 2018). African penguins show spatial and temporal variability in breeding success (Crawford et al. 2006) that is influenced by nest type (Sherley et al. 2012; Pichegru 2013), exposure to oil pollution (Barham et al. 2007; Wolfaardt et al. 2008), predation (Pichegru 2013), human disturbance (Hockey & Hallinan 1981) and, probably most importantly, food availability (Crawford et al. 2006; Durant et al. 2010). Accordingly, there are a number of conservation efforts focused on increasing the breeding output of African penguins, including hand rearing abandoned eggs and chicks (Klusener et al. 2018; Sherley et al. 2014a), construction of artificial nests (Sherley et al. 2012) and fishery management (Pichegru et al. 2012).

In addition to monitoring breeding success, measuring body condition can provide useful information when studying factors affecting penguin colonies. The body condition of an individual is the proportion of its body mass available in the form of metabolisable energy reserves (Lubbe et al. 2014). In altricial birds, chick body condition is directly related to the amount of food delivered by the parents (Lubbe et al 2014). Studies of body condition can therefore tell us about food availability (Campbell et al. 2019). The impacts of other factors on chick condition are not yet widely studied, for example the characteristics of the nest they inhabit, though it is likely that food supply is the overarching factor in influencing body condition (Lubbe et al. 2014; Campbell et al. 2019). It has been shown, however, that yellow-eyed penguins (*Megadyptes antipodes*) in neighbouring colonies had lower fledging weights

at the colony that was exposed to ecotourism, suggesting that human disturbance can have an impact upon body condition (Ellenberg et al. 2007).

Studying the impact of human disturbance on productivity and body condition is important to inform the development of effective management guidelines. Examples of this are suggesting the implementation of visual barriers at Humboldt penguin (*Spheniscus humboldti*) colonies (Ellenberg et al. 2006), and advising the restriction of tourism to Magellanic penguin colonies where visitation is already established (Yorio & Boersma 1992). As the African penguin is an endangered species and the population continues to decline (BirdLife International 2018), it is important to identify some of the factors contributing to lowering breeding success and chick condition in order to inform effective management strategies and implement measures to help increase breeding success and bolster the populations.

The main aims of the present study were to: (1) quantify differences in breeding success and (2) chick condition of African penguins between two colonies in the Western Cape (Fig. 1.1) that are exposed to differing levels of human visitation; as well as evaluate differences within the high visitation colony in (3) breeding success and (4) chick condition between nests along a visitor boardwalk and those in a control area. It was predicted that due to the absence of ecotourism and its associated human disturbance, chick condition and breeding success would be higher at the low visitation colony. It was also predicted that nests in close proximity to the visitor boardwalk at the high visitation colony, which allows tourists to get up close and thereby potentially increasing disturbance, would have lower chick condition and breeding success in comparison to those in the control area away from the boardwalk.

2.3 Methods

2.3.1 Study species

Individual African penguin chicks and nests were chosen for inclusion in this study by selecting nests that were already involved in chick condition and breeding success monitoring programmes at the colonies in order to avoid this research causing further disturbance. For further information on the study species, refer to Chapter 1.5

2.3.2 Study sites

The study took place at two colonies in the Western Cape of South Africa with differing rates of human visitation. The high visitation colony is a mainland colony and an ecotourism attraction, namely Stony Point, in Betty's Bay. The low visitation colony is Robben Island that does not experience ecotourism (Fig. 1.1). For further information on the study sites, refer to Chapter 1.6.

2.3.3 Data Collection

Chick condition measurements were made from the middle of the breeding season in 2017, from 14th July to 10th October. Breeding success monitoring data was collected across the whole breeding season of 2017 (from April to October) by staff and researchers involved in the monitoring projects, and data for the nests involved in this study were subsequently provided for analysis. At Stony Point, data from 85 nests was collected in collaboration with CapeNature, and on Robben Island, data from 47 nests was collected in collaboration with the Earthwatch Institute and the Southern African Foundation for the Conservation of Coastal Birds (SANCCOB). Nests at the Stony Point colony were selected within 5 m (n=20) and 10 m (n=20) of the visitor boardwalk and within a control area (n=45) that the boardwalk does

not run through, in order to ensure areas with differing levels of human exposure were monitored for comparison.

On Robben Island, breeding success data was collected at a target interval of 4-7 days (Sherley et al 2018), and 7-9 days at Stony Point (C Hugo pers. comm., CapeNature). Upon each visit to the nests, the contents were recorded. When chicks were present, they were classified into development stages: P0 - newly hatched chicks (< 6 days old); P1 - small downy chicks (~ 6-15 days old); P2 - medium to large downy chicks (~ 16-35 days old); P3 - large downy chicks (~ 36-45 days old); and P4 - chicks with over half their body in final fledgling plumage (> 45 days old) (Barham et al. 2007; Sherley et al. 2014a).

Breeding success was calculated using an extension of the Mayfield (1961) method developed by Sherley et al. (2013). The mid-point between nest visits was used to calculate the total number of days over which eggs and chicks were in the nest and exposed to potential failure (nest days; Mayfield 1961, 1975). Chicks were considered to have successfully fledged if they reached the P4 stage (Sherley et al. 2013) and were considered to have died if they disappeared after less than 40 days. Eggs that were incubated for >50 days and did not hatch were considered to have failed and were assumed to be infertile. In these cases, their estimated nest day values were reduced to 40 days to avoid inflating incubation success estimates (Sherley et al. 2013). Mortality rates were estimated using the 'flexsurvreg' function from the 'flexsurv' package (Jackson 2016) for R (R Development Core Team 2018). The fit of the data to Gompertz, exponential, Weibull and Log-normal hazard functions were compared using AICc (using the 'ICtab' function from 'bbmle' library), with the model returning the lowest AICc used for inference. A Gompertz error distribution was consequently used to estimate incubation success, and a lognormal error distribution was

used to estimate chick rearing success. Mortality rates were converted to survival estimates and bootstrapped 95% confidence intervals using the summary method for flexsurvreg objects (Jackson 2016) and t = 40 days for incubation and 74 days for chick-rearing (Sherley et al. 2012, 2013). Survival rates during incubation and chick rearing were calculated separately due to the differing mortality rates associated with these two stages (Seddon & van Heezik 1991). Overall breeding success was therefore the product of the survival rates of the nest contents during both incubation and chick rearing (Sherley et al. 2012).

2.3.4 Chick condition

On each visit to the study nests, the nest contents was recorded and for each chick present with a head length of >75 mm as stipulated in Lubbe et al. (2014), mass was measured using a spring scale (measured to the nearest 10 g) and head length was measured using callipers (±0.1 mm). Chick body condition was calculated using the BCI4 modified Veen index method, which is considered the most appropriate method for calculating the average condition of a group of chicks at a given time, and for comparisons between colonies (Lubbe et al. 2014). The BCI4 modified Veen index is defined as:

(observed mass – predicted minimum mass)/

(predicted maximum mass – predicted minimum mass)

This method is a relative index as it uses a data set from Robben Island in 2004 as a baseline (Lubbe et al. 2014). The resulting index after calculation can be interpreted as chicks with an index value above zero being considered to have an above average body condition, and chicks with an index value below zero being considered to have a below average body condition.

Chick condition between Robben Island and Stony Point was compared using the Welch's Two Sample t-test. The Welch's Two Sample t-test was also used to compare chick condition between chicks in nests along the visitor boardwalk at Stony Point and those in the control area away from the boardwalk. All statistical analyses were carried out using the R software, Version 3.5.1 (R Development Core Team, 2018).

2.4 Results

2.4.1 Breeding success between Robben Island and Stony Point

During the 2017 breeding season, incubation success (0.903), chick rearing success (0.938) and overall breeding success (0.848) were all higher on Robben Island than at Stony Point (0.476, 0.589 and 0.281 respectively); in all cases there was no uncertainty in these differences with no overlap in the 95% confidence intervals (Fig. 2.1, Table 2.1).

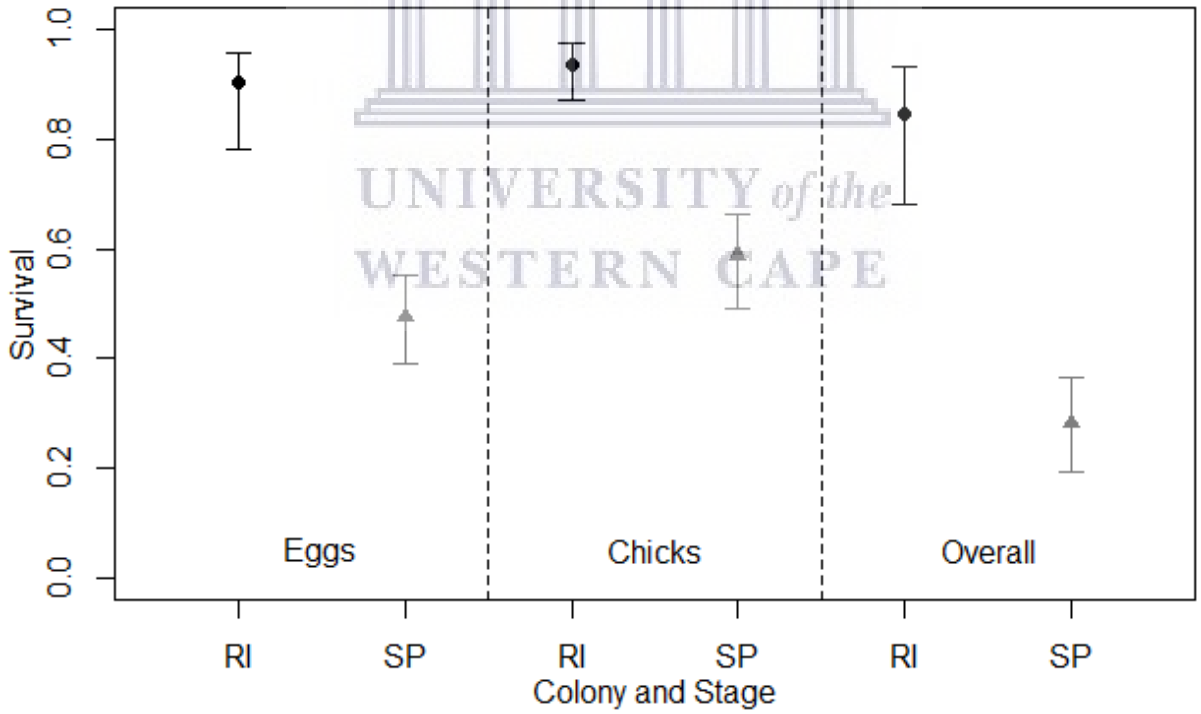

Figure 2.1. Estimated survival probabilities and 95% confidence intervals of eggs at 40 days post-laying, chicks at 74 days post-hatching, and the overall breeding success of African penguins at Robben Island (RI) and Stony Point (SP).

Table 2.1. Hatching, fledging and overall breeding success on Robben Island and Stony Point, South Africa in 2017.

Stage	Variables	Robben Island	Stony Point
Incubation period (eggs)	N nests	47	85
	N eggs	91	178
	N failures	5	80
	N nest days	2274.5	5462.5
	Survival probability	0.903	0.476
	95% confidence intervals	0.779-0.958	0.398-0.547
Chick rearing period (chicks)	N nests	49	76
	N eggs	94	136
	N failures	5	54
	N nest days	6577.5	3596
	Survival probability	0.938	0.589
	95% confidence intervals	0.868-0.974	0.501-0.669
Overall breeding success	Survival probability	0.848	0.281
	95% confidence intervals	0.678-0.933	0.199-0.365

2.4.2 Breeding success between areas of differing human visitation rates within the Stony Point colony

Survival estimates during both the incubating and chick rearing period did not differ between nests <5m of the boardwalk, <10m of the boardwalk and within the control area away from the boardwalk, with all the 95% confidence intervals overlapping (Fig. 2.2, Table 2.2). However the point estimates for survival during the chick rearing stage did vary in the hypothesised direction, being lowest <5m of the boardwalk and highest in the control area.

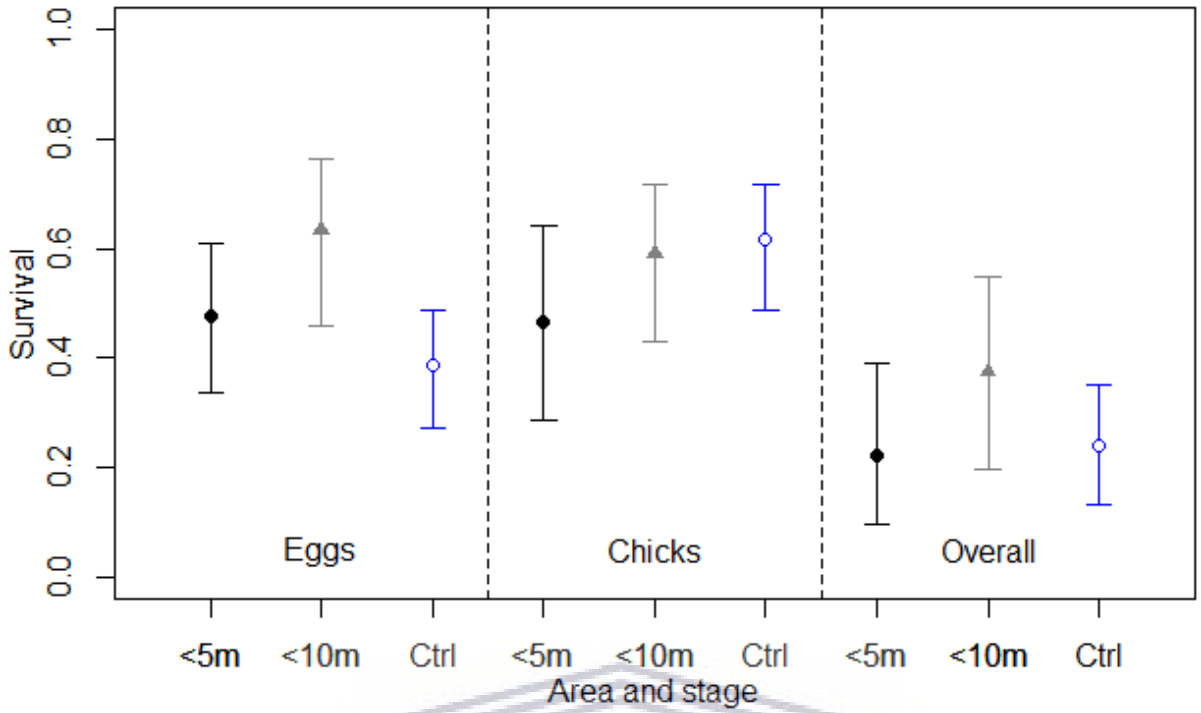

Figure 2.2. Estimated survival probabilities and 95% confidence intervals of eggs at 40 days post-laying, chicks at 74 days post-hatching, and the overall breeding success of African penguins at Stony Point within 5m (<5m) and 10m (<10m) of the visitor boardwalk, and in a control area (Ctrl).

Table 2.2. Hatching, fledging and overall breeding success of nests at differing proximities to a visitor boardwalk at Stony Point, South Africa in 2017.

Stage	Variables	<5m	<10m	Control
Incubation period (eggs)	N nests	20	20	45
	N eggs	42	44	92
	N failures	24	14	42
	N nest days	1430.5	1514.5	2517.5
	Survival probability	0.476	0.635	0.386
	95% confidence intervals	0.337-0.611	0.458-0.763	0.273-0.489
Chick rearing period (chicks)	N nests	14	19	43
	N eggs	26	39	71
	N failures	12	15	27
	N nest days	622.5	856	2117.5
	Survival probability	0.466	0.59	0.617
	95% confidence intervals	0.287-0.641	0.429-0.718	0.486-0.708
Overall breeding success	Survival probability	0.222	0.375	0.238
	95% confidence intervals	0.097-0.392	0.197-0.548	0.133-0.351

2.4.3 Chick condition comparison between chicks at Robben Island and Stony Point

The mean ± SD condition index of chicks at Stony Point was 0.329 ± 0.379 (range = -0.654 to 2.531) (n=158), and the mean ± SD condition index of chicks at Robben Island was 0.521 ± 0.399 (range = -0.495 to 1.784) (n=96) (Fig. 2.4). Chicks at Robben Island were in significantly better body condition than chicks at Stony Point (Welch Two Sample t-test: t = 3.769, $p < 0.001$).

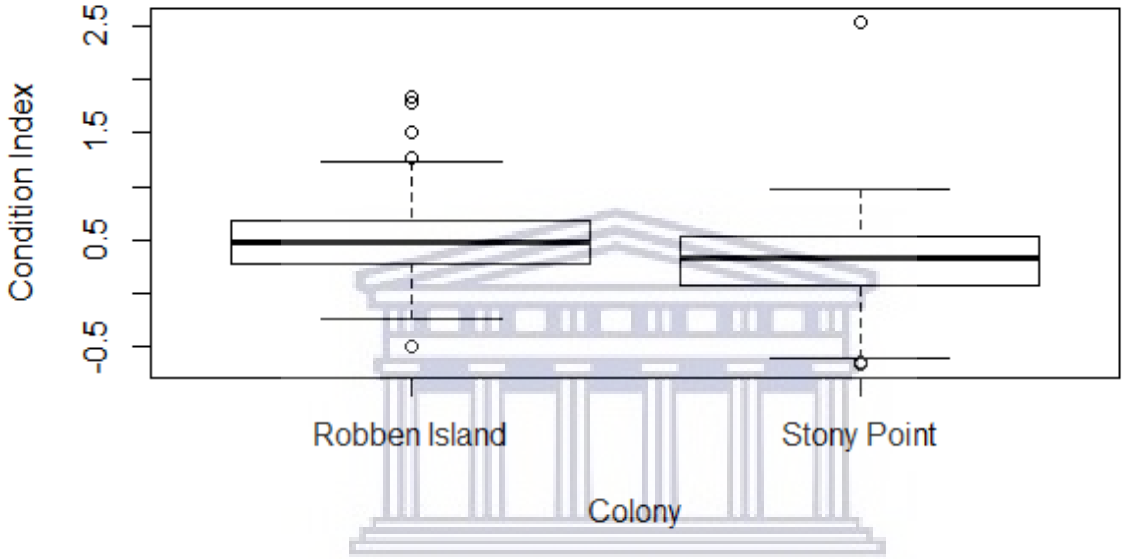

Figure 2.4. Chick condition at Stony Point (n=158) and Robben Island (n=96). The thick black line indicates the median. The box and whisker plots show the interquartile range. Circles indicate outliers.

2.4.4 Chick condition between nests in the control area and nests within 10m of the visitor boardwalk at Stony Point.

Due to the small number of chick condition measurements collected <5m of the boardwalk (n=18), this data was combined and analysed within the <10m category for comparison with the control area. Chick condition measurements were taken from 71 chicks <10m of the boardwalk, and from 87 chicks in the control area away from the boardwalk. The mean ± SD chick condition index of chicks <10m of the boardwalk was 0.397 ± 0.438 (range = -0.646 to 0.974). The mean ± SD chick condition of chicks in the control area away from the

boardwalk was 0.275 ± 0.316 (range = -0.594 to 0.973) (Fig. 2.3). There was no significant difference in body condition indices between birds along the boardwalk than chicks in the control area, though there was a tendency for chicks in the control area to be in poorer condition than chicks along the boardwalk (Welch Two Sample t-test: $t = 1.972$, $p = 0.051$).

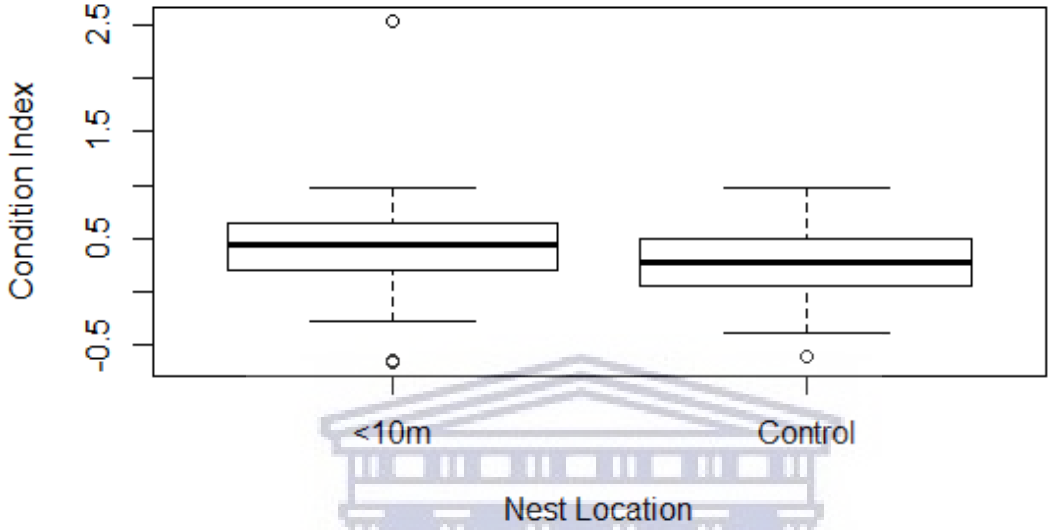

Figure 2.3. Chick condition index of chicks <10m of the visitor boardwalk (n=71) and in a control area (n=87) within the Stony Point colony. The thick black lines indicate the median. The box and whisker plots show the interquartile range. Circles indicate outliers.

2.5 Discussion

Overall, the results indicated that during the 2017 breeding season, egg survival, chick survival and overall breeding success, were higher in the low visitation colony, Robben Island. Similarly, chick condition was significantly higher among chicks on Robben Island than at the colony exposed to ecotourism. Within Stony Point, there was little variability in breeding success and chick condition between boardwalk nests (both <5m and <10m) and nests in the control area, although chicks in the control area tended to have a lower body condition than chicks closer to the boardwalk.

Human disturbance has previously been shown to have a negative impact upon African penguin breeding success. Human passage within the Jutten Island colony (Fig. 1.1), situated

in the West Coast National Park of the Western Cape, was shown to cause the loss of eggs through predation, and also prevented birds prospecting for nests (Hockey & Hallinan 1981). Similarly, reduced breeding success in tourist visited sites has also been observed in Humboldt penguins (Ellenberg et al. 2006) and yellow-eyed penguins (McClung et al. 2004; Ellenberg et al. 2007) where tourists were able to walk freely on the landing beaches and approach penguins within a few metres.

While the inter-colony breeding success and chick condition results are in line with the hypothesis that they would be lower at the high visitation colony, the extent to which breeding success is higher on Robben Island is surprising when also considering the impact that limited prey availability has been shown to have upon the colony (Sherley et al. 2013). Penguins are considered marine sentinels, and their breeding success can provide much insight into the state of the oceans, including regional ocean productivity (Boersma 2008). Given the recent eastward shift of the African penguin's main prey items of anchovy (*Engraulis encrasicolus*) and sardine (*Sardinops sagax*) (Mhlongo et al. 2015) we may expect the breeding success and chick condition to be lower on Robben Island than is reported here. The breeding success rates reported for Robben Island in this study are much higher than has been reported in previous years (e.g. 39.3% breeding success rate over the years 2001 to 2010 (Sherley et al. 2012)). Pelagic recruitment surveying showed 2017 to be a good year in terms of anchovy recruitment, exceeding the averages in both number and biomass along the coast of South Africa (Shabangu et al. 2019). Robben Island birds may therefore be showing a positive response to the high food availability when compared to previous studies that took place during years of poorer food availability. These results could also be a product of sample size, with only a subset of the nests monitored for the long term monitoring project (47 out of 167) being included for analysis as per the original study design. This may be impacting the

reliability of the results and may not be representative of the breeding success and chick condition of all nests and chicks monitored at Robben Island in 2017.

This study found that penguins at the high visitation colony, Stony Point, experienced lower breeding success and chick condition than penguins at Robben Island. In yellow-eyed penguins, tourism was shown to impact fledging weights as the parents returning from sea were hesitant to pass the tourists present in order to return to their nests and feed their chicks (McClung et al. 2004). The boardwalk at Stony Point is elevated and allows the passage of penguins underneath it, however, the birds may still be hesitant to return to their nests as they are still able to see the tourists that are on the boardwalk. Breeding success has previously been shown to be negatively related to nest density, particularly during the chick rearing period (Sherley et al. 2014b) and Stony Point initially experienced a rapid increase in numbers (Crawford et al. 2011), though this number has declined in recent years (from 2,533 pairs in 2015 (BirdLife International 2018) to 1,774 pairs in 2017 (CapeNature, unpublished data). The Robben Island colony on the other hand declined rapidly (Crawford et al. 2011), though it is more stable in recent years (1,126 pairs in 2015 (BirdLife International 2018) and 1,440 in 2017 (Department of Environment, Forestry and Fisheries, unpublished data)). The resulting higher density of nests at Stony Point may therefore be contributing to the lower breeding success. High nest density could potentially be impacting breeding success due to the associated increase in parasites. African penguin colonies with a higher nest density have higher parasite infestations (Espinaze et al. 2019). These parasites are found more commonly on chicks as opposed to adults (Espinaze et al. 2019) and can transmit diseases which affect survival of the host (Nuttall 1984). Other potential consequences of high nest density on breeding success are increased attacks by adults on chicks that wander from their nests (Seddon & van Heezik 1993) and fights over nest sites (Eggleton & Siegfried 1979). It may

therefore be a combination of both higher human visitation rates and higher nest density causing the comparatively lower levels of breeding success and chick condition observed at Stony Point.

While chick condition was not significantly different between chicks nesting along the boardwalk at Stony Point and those in the control area that is not exposed to ecotourism, a tendency towards chicks in the control area being in poorer condition was observed. The boardwalk does not go through the control area of the colony and entry to this area is strictly prohibited to the general public, so the birds within that area are subjected to a much lower level of human visitation than those along the boardwalk. All the birds at Stony Point have access to the same food source, so this result suggests that chick condition is not solely indicative of food availability and other factors may also have an impact. Chicks along the boardwalk may be in better condition due to the boardwalk itself providing protection and shade from the heat. Stony Point was only colonised by penguins in the 1980s (Underhill et al. 2006) so there is no build-up of guano for them to create safe burrows that can protect them from temperature fluctuations (Frost et al. 1976). Instead they have to nest on the surface or in other sub-optimal habitats (Wilson & Wilson 1981). Penguins have been shown to suffer from heat stress at sparsely covered nests (Seddon & Davis 1989). The birds along the boardwalk may potentially be receiving more shelter than those in the control area, which could be impacting the condition of chicks there. Further studies including additional variables such as nest characteristics and environmental conditions may be valuable in order to investigate the reasons behind this result.

An additional impact that human presence can have upon penguin breeding colonies is the facilitation of predation (e.g. Giese 1996). A common response of penguins to human

approach is to temporarily flee the nest in order to get away from the source of disturbance (Seddon & Ellenberg 2008), which can have serious consequences when an adult is incubating an egg or rearing a small chick as it leaves them exposed to predators. For African penguins, these predators include kelp gulls who feed on the eggs or small chicks (Pichegru 2013). African penguins that breed on mainland, such as those at Stony Point, are also exposed to land-based predators that are not found on islands, including Cape grey mongoose (*Galerella pulverulenta*), caracal (*Caracal caracal*), domestic dog (*Canus lupus familiaris*) and leopard (*Panthera pardus*) (BirdLife International 2018; Vanstreels et al. 2019). Predation, not necessarily facilitated through human disturbance, may explain why the breeding success and chick condition was lower at the Stony Point mainland colony.

Due to the wide range of variables that can have an impact upon the breeding success of African penguins, it is challenging to ascertain the potential impact of ecotourism on penguins' productivity. The results presented here suggest that ecotourism may possibly be having a negative impact upon the breeding success and chick condition of birds at Stony Point, but the limited scope and sample size of this study prevents any strong conclusions. Further research is therefore required in order to rule out the impact of other factors such as food availability, predation or nesting conditions.

A multi-year study comparing breeding success and chick condition at Robben Island and Stony Point, but also including colonies with higher and lower visitation rates would be essential in order to further investigate the impact of ecotourism at differing intensities, and building in visitor number data from each year into the analysis could enable a more in depth assessment. The Boulders Beach colony experiences higher levels of human visitation with 930,000 visitors in 2017 (van Zyl & Kinghorn 2018) in comparison to Stony Point that saw

72,500 in the same year (CapeNature, unpublished data). Dassen Island (Fig. 1.1) is uninhabited and does not experience tourism in any form. It is only occasionally visited by researchers, and could therefore be a suitable control colony for a future study. It may also be important to factor in food availability of the years in question to the analysis as this is shown to have a large impact on both breeding success and chick condition.

As a potential impact of human disturbance is the facilitation of predation, an observational study looking into the occurrence of predation events, such as kelp gulls predating eggs following the disturbance of incubating penguins that may consequently temporarily abandon the nest, using camera traps or human observers related to visitor numbers may provide more information on whether ecotourism is impacting the colony. If it is shown to be an issue, the impacted colonies could consider improving breeding habitat through the provision of more shelter through a programme of increasing vegetation in the colony and potentially through artificial nests. While artificial nests have been shown to be effective in increasing the breeding success of colonies through protection from aerial predators such as gulls (Pichegru 2013), this potential intervention method would require investigation as the success of artificial nests has been shown to be site and design dependent (Sherley et al. 2012, Lei et al. 2014), and parasite concerns have been noted in artificial nests at Stony Point (Espinaze 2018).

2.6 Conclusion

Ecotourism can be advantageous to wildlife and conservation through generation of funds that contribute to conservation, and education of the public (Yorio et al. 2001, van Zyl 2014), but it is important that it is managed on a species and site specific basis (Seddon & Ellenberg 2008). The results presented in this chapter suggest that ecotourism may be having a negative

impact upon the breeding success and chick condition of birds at the Stony Point penguin colony, though due to the number of other factors that impact these parameters, it is difficult to make firm conclusions. For this reason, a future multi-year study considering ecotourism visitor numbers and environmental factors such as rates of predation and food availability may be useful in order to obtain a more in depth look at the impact that ecotourism has upon African penguin colonies.

Chapter 3 – Impact of human disturbance on faecal corticosterone levels of African penguin chicks

3.1 Abstract

Over the past century the African penguin (*Spheniscus demersus*) population has undergone a severe decline in numbers, resulting in the species being listed as Endangered on the International Union for Conservation of Nature (IUCN) Red List in 2010. Penguin colonies are popular tourist attractions, and there is increasing concern on the impact that this disturbance is having upon the birds. In this study, the non-invasive method of assessing faecal glucocorticoid metabolites was used to investigate the levels of stress in chicks at two African penguin colonies in the Western Cape of South Africa that differ in rates of human visitation; one that experiences ecotourism and one that does not. Stress levels were also investigated within the high visitation colony by comparing chicks at nests along the visitor boardwalk and those in a control area away from the boardwalk. The results suggest that tourism at the high visitation colony does not increase chick stress levels and the current management of visitors is effective. Stress levels at the low visitation colony were significantly higher, but as ecotourism does not occur here, it may be an indicator of environmental stress rather than human disturbance. A future multi-year study taking visitor numbers directly into account and including other colonies that experience differing levels of ecotourism and human visitation may reveal more about the impact that this form of human disturbance has upon African penguin chicks.

3.2 Introduction

Stress is known to have an impact on the immune system, reproduction and behaviour of an individual (Touma & Palme 2005), and measuring stress can therefore provide valuable

information on the health of an animal and its population. When an individual faces a stressor, a stress response is initiated. A stress response involves the activation of the hypothalamic-pituitary-adrenal (HPA) axis and secretion of glucocorticoids from the adrenal gland (Cockrem 2007). The result of this is behavioural and physiological changes that enable the individual to overcome the challenge or stressful event (Romero 2004; Palme et al. 2005). However, chronic activation of the stress response can lead to changes in the adrenocortical activity that may hinder the affected individual's ability to respond appropriately to other serious threats in the future (Romero 2004), such as reduced resistance to disease, overall lower survival (McEwen 1998) and decreased reproductive output (Thierry et al. 2013). As such, measuring the glucocorticoid concentrations of individuals as a proxy of the stress response offers an ideal technique with which to determine the welfare of a population.

Stress levels in animals can be monitored using invasive and non-invasive techniques. Taking blood samples is considered an invasive technique as it requires handling and restraint of the individual. The stressful nature of this protocol induces increases in stress hormones, as blood glucocorticoid levels increase significantly within 2-5 minutes of capture. This time frame is often too short to collect the sample in the field, which renders the estimation of a true baseline stress level difficult using this method (Sheriff et al. 2011). Alternative comparatively non-invasive methods to measure stress levels include the collection of feather, urine and faecal samples. Glucocorticoids are metabolised by the liver and are excreted via urine and bile (Palme et al. 2005). This metabolism results in a time delay between a stressful event and it reflecting in the sample, so the stress associated with handling or human approach whilst collecting such samples is not reflected. However,

knowing the time delay for the particular species studied is vital for analysis as it differs from species to species (Palme 2005). Faecal sampling has been widely used to measure stress in vertebrates (Sheriff et al. 2011), for example, African penguins in captivity (Ozella et al. 2015), numbats (*Myrmecobius fasciatus*) (Hogan et al. 2012) and African elephants (*Loxodonta africana*) (Ganswindt et al. 2010). This method provides a cumulative measure of stress as opposed to the immediate representation of an individual's current state in that instance such as is provided in blood plasma samples (Sheriff et al. 2011). As the collection of faecal samples is non-invasive in comparison to blood sampling, it can allow for repeated samples to be taken over a long period of time with no likely negative impact upon the animal, and therefore opening up the possibility for longitudinal studies. Collection of faecal samples from some species, however, does require entering breeding areas and approaching individuals at close proximity in order to collect the samples, so it is not always completely non-invasive.

This technique has become increasingly popular in ecological studies (Romero 2004) and has been undertaken for a number of penguin species, including gentoo penguins (*Pygoscelis papua*) (Lynch et al. 2019) and African penguins (Ozella et al. 2015; Ozella et al. 2017). In birds, the major glucocorticoid hormone released is corticosterone; the release of this hormone results in changes that help an individual to respond to a stressor. These changes include increases in blood glucose levels and behavioural changes (Sapolsky et al. 2000). Measuring the levels of this hormone can determine to what degree an individual is experiencing stress (Cockrem 2007).

Chapter 3 – Impact of human disturbance on faecal corticosterone levels of African penguin chicks

With the global increase of ecotourism (Sharpley 2006), and the consequent increase in human presence within the habitats of wild animals, it is important to understand the impact this activity may be having, including how it affects the stress levels of the animals involved. Studies across a number of penguin species show that different species react differently to human presence. In Humboldt penguins (*Spheniscus humboldti*) and yellow-eyed penguins (*Megadyptes antipodes*), birds that were exposed to human visitation exhibited higher stress responses than undisturbed birds (Ellenberg et al. 2006; Ellenberg et al. 2007). In contrast to this, some penguin species show potential for habituation to human activity, with birds in areas of frequent human visitation showing a significantly lower behavioural or physiological stress response than those in areas of low human visitation. These species include African penguins (van Heezik & Seddon 1990; Pichegru et al. 2016), king penguins (*Aptenodytes patagonicus*) (Viblanc et al. 2012), and Magellanic penguins (*Spheniscus magellanicus*) (e.g. Fowler 1999; Walker et al. 2006; Villanueva et al. 2012). No relationship was found between the physiological stress response and tourism in gentoo penguins (Lynch et al. 2019), though behaviourally the stress response has been shown to be stronger in individuals in undisturbed areas (Holmes et al. 2006). These differences demonstrate the need for studies of stress and the resulting management strategies to be species specific.

African penguins have previously been shown through behavioural responses to exhibit an elevated stress response at colonies with low levels of human exposure in comparison to colonies with high levels of human exposure (Pichegru et al. 2016). In addition to this, a study on captive African penguins in a zoo facility showed that the number of visitors did not affect the adrenocortical activity of the penguins (Ozella et al. 2017). These studies suggest that this species is tolerant to human presence. The present study aims to build on this

information already known on African penguin responses to human visitation, particularly in the context of ecotourism. There are currently two mainland African penguin colonies that allow tourist visitation in the Western Cape of South Africa, namely the Simon's Town (including Boulders Beach) colony and the Stony Point colony in Betty's Bay (Fig. 1.1). Analysing and understanding the physiological stress response of African penguins to human visitation provides an opportunity to inform management authorities of any potential impact that tourists may be having on the species. If necessary, mitigation measures could then be devised to ensure a positive outcome for both the tourism industry and the conservation of these colonies of endangered African penguins.

The main aims of this study were to (1) evaluate the differences in faecal glucocorticoid metabolite (FGM) levels of African penguin chicks between two colonies in the Western Cape (Fig. 1.1) exposed to differing levels of human visitation; and (2) compare FGM levels between nests along a visitor boardwalk and those in a control area away from the boardwalk within the colony that experiences higher levels of human visitation. This study predicts that due to the high levels of human visitation, stress levels will be higher in chicks at the higher visitation colony that experiences the effects of ecotourism, and higher in chicks along the visitor boardwalk in comparison to those in the control area of the high visitation colony.

3.3 Methods

3.3.1 Study species

This study involved African penguin chicks at two colonies in the Western Cape of South Africa. Chicks were the chosen age class for monitoring in this study as opposed to adults. This was to avoid causing further disturbance as the individuals included in this research

were already included in the chick condition monitoring programmes. For further information on the study species, refer to Chapter 1.5.

3.3.2 Study sites

The study took place at two colonies in the Western Cape of South Africa with differing levels of human visitation. The high visitation colony is a mainland colony and ecotourism attraction, namely Stony Point, in Betty's Bay, and the low visitation colony is Robben Island which does not experience ecotourism (Fig. 1.1). For further information on the study sites, refer to Chapter 1.6.

3.3.3 Data Collection

Data collection took place from the middle of the breeding season in 2017 from 14th July to 10th October. At Stony Point, data was collected in collaboration with CapeNature, and on Robben Island, data was collected in collaboration with the Earthwatch Institute and the Southern African Foundation for the Conservation of Coastal Birds (SANCCOB).

3.3.4 Urofaecal sample collection

In birds, urine and faeces are mixed together in the cloaca (Klasing 2005) and excreted as a single urofaecal sample. Urofaecal samples were collected whilst chicks were being measured for condition which involves measuring head length and body mass. A clean plastic tray or sandwich bag was placed beneath the chicks to collect any excreted urofaecal samples while condition measurements were taken. As far as possible, only the faecal portion of the guano was collected and transferred to the collection tube. Tubes containing the samples were frozen as soon as possible after collection. Samples were packaged in dry ice for

transportation from the University of the Western Cape, Bellville to the Endocrine Laboratory at the National Zoological Garden (NZG), South African National Biodiversity Institute, Pretoria, where they were extracted and analysed.

3.3.5 Sample extraction

The frozen urofaecal samples were lyophilized, pulverized and sieved through a thin mesh to remove any fibrous material (Fieβ et al. 1999). Subsequently, 50-55 mg of urofaecal powder was extracted by vortexing for 15 min with 1.5 ml 80% ethanol. Following centrifugation for 10 min at 1500xg, the supernatant was transferred into a new, pre-labelled 2 ml microcentrifuge tube and stored at −20˚C until analysis.

3.3.6 Steroid analysis

The enzyme immunoassay (EIA) analysis was conducted at the Endocrine Research Laboratory, University of Pretoria, South Africa. The urofaecal extracts were analysed with an 11β-hydroxyaetiocholanolone (69a) assay; the reliability of the EIA for monitoring adrenocortical activity in the African penguin has been shown in Anfossi et al (2014) and Ozella et al (2015). Ozella et al. (2015) also demonstrated that FGM levels in African penguins begin to increase after 5 hours and decrease within 30 hours of experiencing a stressor. We therefore assume that the FGM concentrations observed in this study reflect cumulative chronic stress experienced the day prior to faecal sample collection and is not affected by the handling associated with the chick condition measurements. Samples from the same individual chick were also not collected within two weeks of each other to ensure that the handling did not have an impact upon the results.

Details of the EIA, including cross-reactivities, are given by Frigerio et al. (2004). Serial dilutions of extracted samples gave displacements curves that were parallel to the respective standard curves in all assays. Intra- and inter-assay coefficient of variation, determined by repeated measurements of high- and low-value quality controls, ranged between 5.10% and 7.61%. The sensitivity of the EIA was 9 ng/g dry weight.

3.3.7 Statistical analysis

The Mann-Whitney-Wilcoxon test was used to compare FGM concentrations between the two colonies (Robben Island and Stony Point). The Mann-Whitney-Wilcoxon test was also used to compare FGM concentrations between the nests along the boardwalk and those in the control area at Stony Point. A non-parametric test was used as residuals from the parametric equivalent test did not meet the normality assumptions required. Statistical analyses were carried out using the R software, Version 3.5.1 (R Development Core Team 2018).

3.4 Results

3.4.1 Differences of FGM concentrations between colonies:

At Robben Island, 25 urofaecal samples were collected from chicks, and 80 were collected from chicks at Stony Point. The mean ± SD FGM concentrations of chicks was 1.34 ± 1.69 µg/g (range = 0.17–8.32 µg/g) at Robben Island and 0.53 ± 0.44 µg/g (range = 0.04–2.46 µg/g) at Stony Point. The difference in medians between the two colonies was statistically significant (Mann-Whitney-Wilcoxon test: W = 1549, p = < 0.001) (Fig. 3.1).

Figure 3.1. Median FGM concentrations (dry weight, µg/g) of African penguin chicks at Robben Island (n= 25) and Stony Point (n=80) in 2017. The thick black lines indicate the median. The box and whisker plots show the interquartile range. Circles indicate outliers.

3.4.2 Differences of FGM concentrations at differing proximities to the visitor boardwalk at the Stony Point colony:

Of the 80 samples collected at Stony Point, 43 urofaecal samples were collected from chicks at nests within the control undisturbed area, and 37 urofaecal samples were collected from chicks at nests within 10 metres of the visitor boardwalk. The mean ± SD FGM concentrations of chicks in the control area away from the boardwalk was 0.5 ± 0.47 µg/g (range = 0.04-2.46 µg/g), with 0.56 ± 0.4 µg/g (range = 0.05-2.45 µg/g) for chicks in nests within 10m of the visitor boardwalk. The median FGM concentrations between chicks from the two areas did not differ significantly (Mann-Whitney-Wilcoxon: W = 620.5, p-value = 0.092) (Fig. 3.2).

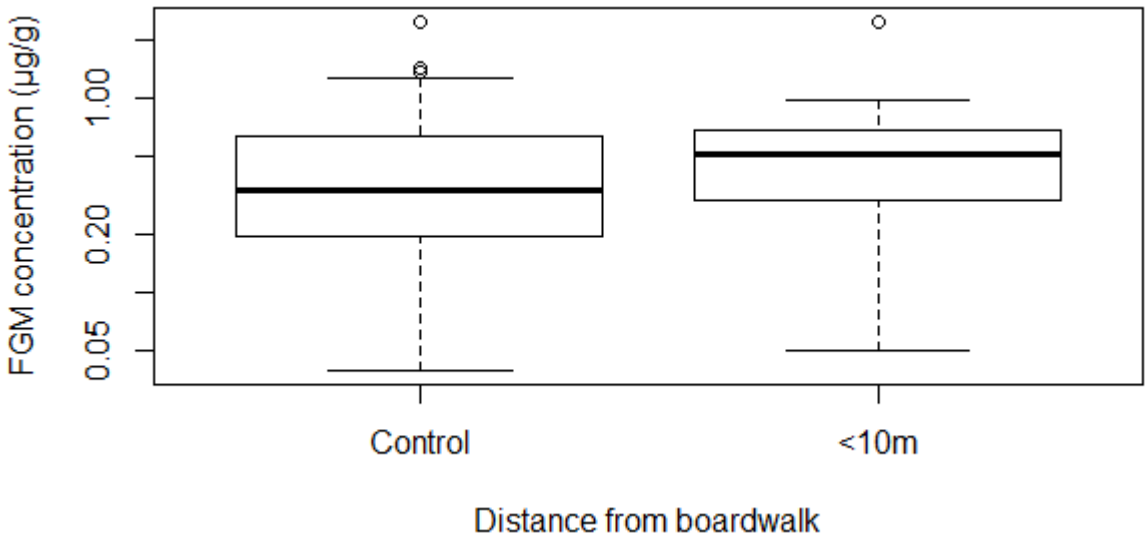

Figure. 3.2. Median FGM concentrations (dry weight, µg/g DW) of African penguin chicks at the Stony Point colony in the control area (n=43) and within 10m of the visitor boardwalk (n=37) in 2017. The thick black lines indicate the median. The box and whisker plots show the interquartile range. Circles indicate outliers.

3.5 Discussion

Overall, the present results suggest that the current visitor management practices and the presence of humans at the Stony Point penguin colony do not have a negative impact on the stress levels of African penguin chicks. There was no significant difference in FGM levels between chicks in the control area and chicks along the visitor boardwalk, suggesting that the chicks reared in nests along the boardwalk are tolerant to the disturbance associated with ecotourism. However, while the difference was not significant, chicks closer to the boardwalk did tend to have higher stress levels. FGM levels at Robben Island, the low visitation colony that does not experience ecotourism, were however significantly higher than FGM levels at Stony Point, potentially suggesting other stressors, including environmental stressors, are having an impact.

These results are consistent with findings from a behavioural study on African penguins, in which they were shown to be more tolerant of human approach in terms of behavioural responses at colonies with high levels of human exposure compared to those with less human exposure (Pichegru et al. 2016). The Stony Point colony sees thousands of visitors each year (CapeNature, unpublished data) that visit specifically to see the penguins in their natural habitat. Robben Island is also a very popular tourist destination and has thousands of tourists visiting each year (Cape Town Tourism 2017, 2018) to see the former maximum security prison, but they do not necessarily come across any penguins on their trip and they are prohibited from entering the breeding areas. Penguins at Stony Point as a whole may therefore be more tolerant to human presence, due to the higher level of constant exposure to humans at the colony, in terms of both the regularity of exposure, as well as the proximity as visitors are contained on the boardwalk.

Chicks in the control area at Stony Point may have similar stress levels in comparison to those in close proximity to the tourists due to the management surveys that both groups are subject to on a regular basis (every 2-3 days). These surveys involve colony staff walking throughout the colony to record nest contents and check for abandoned chicks or injured birds. However, while the difference was not statistically significant, the chicks along the visitor boardwalk were shown to have higher stress levels than those in the control area so a repeat study with a larger sample size may be able to reveal more information about the stress levels of the two groups.

The chicks on Robben Island had significantly higher stress levels despite the lower level of human disturbance and the absence of ecotourism. The Robben Island penguin colony has

been shown to be impacted by food availability, with adult and juvenile survival declining along with prey abundance (Sherley et al. 2014c; Robinson et al. 2015; Weller et al. 2016; Campbell et al. 2019). Environmental changes and pressure from fishing during the mid-1990s-2000s caused an eastward shift in anchovy (*Engraulis encrasicolus*) and sardine (*Sardinops sagax*) aggregations (Mhlongo at el. 2015) which are the two most important prey species that make up the bulk of the diet of African penguins (Crawford et al. 2006; Crawford et al. 2011). Considering Stony Point is located further east than Robben Island (Fig. 1.1), i.e. possibly closest to food resources, FGM concentrations from Robben Island chicks may possibly be indicative of other stressors that are not associated with human disturbance, such as environmental stressors, however, 2017 was shown to be a good year for anchovy abundance along the coast of South Africa (Shabangu et al. 2019). The relationship between food availability and stress levels has been investigated in other species such as the common murre (*Uria aalge*), where food availability was negatively correlated with corticosterone secretion (Kitaysky et al. 2007) and this could also be the case for the Robben Island penguins.

In 2019, Robben Island was proclaimed as an MPA (Marine Protected Areas 2019). During the breeding season, African penguins provisioning chicks are range restricted, and need to be able to access sufficient food within 20-40km of the colony (Pichegru et al. 2009). Benefits of MPAs and fishery closures for African penguins have been investigated, and include reducing foraging effort (Pichegru et al. 2010; Campbell et al. 2019) and the potential for improved chick survival and condition (Sherley et al. 2018). This MPA may help to alleviate any potential stress associated with foraging and food availability at the Robben

Island colony if it successfully reduces competition between penguins and industrial fisheries (e.g. Pichegru et al. 2012; Sherley et al. 2018).

Other factors aside from human presence within a colony or food availability can also contribute to the stress levels of an animal. For example oil pollution can affect herring gulls (*Larus argentatus*) and black guillemots (*Cepphus grylle*), which have been shown to exhibit elevated corticosterone levels following oil ingestion (Peakall et al. 1981; Briggs et al. 1997). Predation risk can also have an impact on stress, for example snowshoe hares (*Lepus americanus*) that were experimentally exposed to dogs, simulating the predator threat they face from lynx and coyotes, had elevated glucocorticoid concentrations in comparison to those that were not exposed (Sheriff et al. 2009). Climate change and the associated rise in temperature and incidences of storms have been shown to increase stress levels of Magellanic penguins (Boersma & Rebstock 2014) and little penguins (*Eudyptula minor*) (Dann & Chambers 2013). These examples demonstrate other factors that can contribute to the stress levels of individuals, and should be considered for inclusion in future studies on African penguins for a deeper understanding on the causes of stress in the species.

Moving forward, a multi-year study, which would encompass varying levels of food availability, with larger sample sizes that also considers visitor numbers directly may reveal more about the potential impact of ecotourism upon African penguin mainland colonies. In the present study, urofaecal samples along the boardwalk at Stony Point were only collected on two occasions, which meant it was not possible to perform analyses with meaningful results in terms of investigating FGM concentrations in relation to visitor numbers. It may also be useful to investigate differences in FGM concentrations at different proximities to the

boardwalk at Stony Point i.e. <5 metres and <10 metres. This was an original aim during the planning phase of this study but due to the small sample size collected in the <5 metres category (n=7), it was not feasible. The outbreak of H5N8 avian influenza in seabird colonies along the coast of South Africa in 2018 resulted in research activities being halted in 2018 by the South African Department of Environmental Affairs (Department of Environmental Affairs 2018). This restricted sampling to 2017 and we were therefore unable to increase the sample size in this study. There were 25 urofaecal samples collected at Robben Island and 80 at Stony Point, and the sample size at Robben Island was unable to be increased due to the logistical challenges that were faced associated with accessing the island. As a small sample size can result in low statistical power, further studies should aim to obtain a larger sample size for a more powerful analysis in order to detect statistically significant results.

It may also be valuable to investigate stress across different age classes in African penguins. Studies on Magellanic penguins have shown similar baseline and stress-induced hormone levels between chicks that were ready to fledge, juveniles, and adult penguins (Walker et al. 2015). The stress response output can change and develop over time, and a normal adult stress response is usually only present when the chick fledges (Walker et al. 2005a). However, it has been shown that newly hatched Magellanic penguin chicks in tourist-visited areas exhibit a strong stress response to human approach in comparison to those in undisturbed areas, though baseline levels were similar (Walker et al. 2005b). It was suggested that the chicks may respond in this way due to repeated exposure to the elevated heart rate that parents exhibit in response to human presence (Walker et al. 2005b), and that chicks may therefore be learning to respond from the adults. In the present study, the only age class that was monitored for stress levels was chicks in order to align with the data collection already

taking place at the colonies by the management authorities (chick condition monitoring) and not create further disturbance. It may be useful for a future study to measure stress across different age classes at each colony to measure how the different age classes respond to human disturbance, and to investigate the possibility of chicks learning stress from adults in response to human visitation.

Another non-invasive method of evaluating physiological responses to human disturbance stimuli, that could be used alongside faecal sampling, is the use of egg-shaped (to avoid seeming alien to the adults) heart rate monitors. The monitors are placed within the nest during incubation to record the heart rate of the incubating adult. This method has been used successfully in yellow-eyed and gentoo penguins (Ellenberg et al. 2013; Giese et al. 1999) and was found to be useful in identifying the type of human disturbance that causes an elevated heart rate, with minimum impact from the observer. This method could be useful to evaluate the impact of different specific tourist behaviours upon the penguins, for example motionless observation and wildlife photography (Ellenberg et al. 2013). This information would directly inform management guidelines for tourists within colonies to reduce the impact they have, and should be considered for inclusion in a future study.

Including the Boulders Beach colony in Simon's Town in a future study would be another useful addition as it experiences a higher level of human visitation than Stony Point. Boulders Beach recorded 930,000 visitors in 2017 (van Zyl & Kinghorn 2018) and Stony Point recorded approximately 72,500 visitors in the same year (CapeNature, unpublished data) so a comparison between the three colonies could enable a more in depth assessment of the impact of ecotourism and the associated human disturbance at African penguin colonies in the

Western Cape. The original aim of this study was to include Boulders Beach, but the research permit application was not approved due to concerns over the volume of research already taking place in the colony that year, and the permitting authority wanted to wait for results of this initial study to assess the value of such research before allowing similar research in this colony. The Dassen Island penguin colony could also be useful to include as the island is uninhabited and is only occasionally visited for research purposes. This island could therefore act as a control colony.

3.6 Conclusion

Ecotourism can be advantageous to wildlife and its conservation, but it is important that it is managed on a species and site specific basis (Seddon & Ellenberg 2008). The results presented in this chapter suggest that there is no apparent negative impact of ecotourism on the stress levels of African penguin chicks at Stony Point and that the current visitor management in place at the Stony Point colony may be effective. A future multi-year study that considers visitor number data, different age classes; varying proximities to tourists on a boardwalk, as well as an additional high visitation colony and a low visitation control colony may be useful for a more in depth look at the impacts of ecotourism upon African penguin colonies.

Chapter 4 – General Discussion

4.1 Overview

This thesis focused on the impact of human visitation upon African penguin (*Spheniscus demersus*) colonies in the form of ecotourism. Ecotourism is a fast-growing industry (Scheyvens 1999; Sharpley 2006) and penguin colonies are popular ecotourism destinations amongst tourists seeking out close up encounters with wildlife (Seddon & Ellenberg 2008; Ropert-Coudert et al. 2019). Ecotourism can provide a number of benefits such as the generation of income for conservation initiatives, and provision of education of the public (Yorio et al. 2001; van Zyl 2014), however it is important to identify the impact that this increase in human presence is having upon the populations in question. This is pertinent in the Western Cape of South Africa as there are two easily accessible mainland African penguin colonies open for visitation in close proximity to Cape Town, one of which recorded 930,000 visitors in 2017 (van Zyl & Kinghorn 2018). This thesis therefore aimed to assess the impact of ecotourism upon African penguin colonies by comparing two colonies of differing levels of human visitation in the Western Cape of South Africa during the 2017 breeding season. Stony Point was considered the high visitation colony due to the presence of ecotourism and the thousands of visitors coming to see the penguins each year (CapeNature, unpublished data), and Robben Island was considered the low visitation colony as it is not an ecotourism destination, and the penguins are generally only exposed to a lower level of human disturbance through research activities. As well as investigating differences between the two colonies, a comparison was made within Stony Point which involved comparing birds that nest along the visitor boardwalk, and those that nest within a control area that cannot be accessed by tourists. To look at the differences in both these scenarios, breeding success, chick condition and chick stress levels were measured in order to investigate the potential

impact of ecotourism upon African penguins. In order to avoid this research causing further disturbance, data was collected in collaboration with organisations involved with ongoing research projects at both colonies, and the non-invasive method of faecal glucocorticoid metabolite (FGM) analysis from urofaecal samples to measure stress was used.

4.2 Key findings

Chapter 2 focused on breeding success and chick condition, and Chapter 3 focused on stress levels of chicks. Here the findings of both research chapters are presented together in the context of each colony. In brief, the results showed that breeding success, chick condition and stress levels were all higher at Robben Island. Within Stony Point there was little variability in breeding success, chick condition and stress levels between the boardwalk nests and control nests.

Breeding success was lower in the high visitation colony, Stony Point, which could suggest that the ecotourism activities that occur there may be having a negative impact upon the African penguin population. However, while breeding success was lower overall at this colony, there was no significant difference in breeding success in nests along the visitor boardwalk when compared with those within the low visitation control area at the same colony. Since birds that are exposed to ecotourism and those that are not had similar breeding success rates at the same colony, this suggests that nests being in close proximity to the visitor boardwalk and therefore human visitation may not have been negatively impacted in terms of breeding success, and that there are other factors beyond the scope of this study that may be affecting the breeding success of the Stony Point colony as a whole. Human disturbance has been shown to facilitate predation of penguin eggs and small chicks due to temporary abandonment of nests in response to human approach (e.g. Giese 1996; Hockey &

Hallinan 1981), and the resulting loss of eggs or chicks can have an impact on the breeding success of a colony. Many African penguins now experience an enhanced risk of such predation as many birds breed in surface nests following the historical scraping of the guano into which they would historically burrow, as well as relatively newer colonies such as Stony Point that did not have this guano build up to begin with. Surface nests do not provide the same protection from aerial predators as burrow nests do (Pichegru 2013). In addition to this, as a mainland colony, it is exposed to the threat of predators that are not present on islands, for example leopards (*Panthera pardus*) which have previously reduced the size of the colony and resulted in many failed eggs (Whittington et al. 1996). There were no reported predation events by leopards in 2017, but other land-based predators such as Cape grey mongoose (*Herpestes pulverulenta*) or caracals (*Caracal caracal*), as well as kelp gulls (*Larus dominicanus*) could potentially be influencing the comparatively low level of breeding success at this colony.

As well as breeding success, chick condition was generally lower among chicks at Stony Point than on Robben Island, but there was little variability within the colony. Tourism has been shown to impact the fledging weights of yellow-eyed penguins (*Megadyptes antipodes*) due to hesitation of the parents to return to nests and feed chicks after being at sea while humans are present at the colony (McClung et al. 2004). The elevated and fenced visitor boardwalk allows for passage by penguins underneath at Stony Point so there is not a physical barrier for the adults to return to their nests, though they are able to see the tourists on the boardwalk and may still be hesitant to walk underneath it to return and feed their chicks.

Breeding habitat at Stony Point may be sub-optimal habitat for successful breeding. For example the higher nest density in comparison to Robben Island may be resulting in higher parasite loads (Espinaze et al. 2019). Additionally, environmental conditions such as temperature could possibly be inducing heat stress, and chicks along the visitor boardwalk could be receiving better protection from the elements due to the boardwalk itself and the shelter it provides, resulting in the condition of the chicks in the control area being lower. A combination of these factors could be the reason the Stony Point colony as a whole is showing lower breeding success and chick condition in comparison to Robben Island that experiences a lower level of human visitation, but further research is required to investigate this.

Despite the lower levels of chick condition and breeding success observed at Stony Point, the results showed that chicks were less stressed than those on Robben Island. This suggests that the visitor management currently in place for tourists at Stony Point is probably effective at preventing increased stress levels of the chicks. This idea is reinforced by the results that indicate stress levels were not significantly different among chicks along the boardwalk and those in the control area at Stony Point, though it did appear to be slightly higher in birds along the boardwalk. These findings suggest that the proximity of the boardwalk that enables visitors to get close to the nests is not negatively impacting chicks in terms of causing high levels of stress. These results are consistent with a behavioural study of African penguins that showed higher tolerance to human approach among birds at colonies with high levels of disturbance in comparison to those with low levels of disturbance (Pichegru et al. 2016). While these birds at high visitation colonies may have a higher tolerance to human presence in terms of stress levels, it is still important that ecotourism destinations are well managed in order to avoid increasing the stress of the individuals that inhabit these areas, as repeated

exposure to stressors can lead to changes in the stress response that may hinder the affected individual's ability to respond appropriately to serious threats in the future (Romero 2004).

The results of this thesis showed that breeding success was higher at Robben Island, and was in fact much higher than has been reported in previous years (e.g. Sherley et al. 2012, 2013). Food availability has been shown to impact the birds on Robben Island, and 2017 was a good year for anchovy (*Engraulis encrasicolus*) biomass and abundance (Shabangu et al. 2019). Anchovy is one of their main prey items, so this may explain the high level of breeding success reported in this study as breeding success is often reflective of ocean productivity (Sherley et al. 2013). Chick condition was also higher among chicks on Robben Island, and as chick condition in altricial species such as the African penguin is directly related to the amount of food fed to them by their parents (Lubbe et al. 2014), this result may also be explained by the abundance of anchovy recorded in 2017. The observation of such high breeding success in this study may be due to the fact that the analysis was only based on a subset of all the nests that are monitored as part of larger ongoing research project, as per the study design, and therefore only provides a snapshot of the situation. This could be impacting the reliability of the results presented in this study.

Although breeding success and chick condition were significantly higher on Robben Island, the stress levels of chicks were also significantly higher despite the absence of ecotourism activities. A study on Magellanic penguins (*Spheniscus magellanicus*) showed that birds in areas that were only exposed to moderate levels of human disturbance did not habituate over a period of a few years, while those that were exposed to very high levels had habituated and did not respond to humans as stressors (Fowler 1999). Over the breeding season on Robben Island, researchers enter the breeding habitat at Robben Island every 2-3 days, and this

comparably low frequency of disturbance may be causing stress without being frequent enough for the birds to eventually habituate. Considering this, investigating the impact of research activities at Robben Island upon stress levels may be useful as chronic activation of the stress response can lower survival (McEwen 1998) and reproductive output (Thierry et al. 2013). It is also important to consider the possible effect that the smaller number of urofaecal samples for Robben Island, in comparison to Stony Point, may have had on the results and the power of the analysis performed, however the sample size could not be increased in this study due to a number of logistical problems and adverse weather conditions.

4.3 Future research

For further research into the effects of ecotourism at African penguin colonies and the associated human visitation upon breeding success, chick condition and stress, it would be valuable to design a multi-year study that includes data on visitor numbers. Due to the study design and the resulting small number of urofaecal sampling days in this study, it was not possible to relate the stress levels found here to visitor number data as originally planned. This would be a useful addition as the results could provide data that could inform a potential visitor number threshold if deemed necessary. As well as visitor number data, predation, heart rate, nest type, and food availability would be valuable to include in a future study in order to be able to draw firm conclusions about ecotourism from the results.

In this thesis, stress levels were only measured in chicks. This was to prevent the study causing further disturbance by only including individuals that were already included in the chick condition monitoring programmes. In Magellanic penguin chicks, a robust stress response is not displayed until fledging age (Walker et al. 2005a) though there is some evidence of the chicks learning to respond early from their parents in tourist-visited areas

(Walker et al. 2005b). Measuring stress levels of only chicks may therefore not be a fair comparison for studies between high and low disturbance colonies, and involving other age classes that do have a robust response may be valuable to ensure stress levels of the colony as a whole are captured.

In addition to the two African penguin colonies included in this project, it may be useful to include comparisons with other colonies that experience higher and lower levels of human visitation. The Boulders Beach colony in Simon's Town experiences a higher level of human disturbance than Stony Point, with 930,000 visitors recorded in 2017 (van Zyl & Kinghorn 2018) compared to the 72,000 recorded at Stony Point in the same year (CapeNature, unpublished data). This comparison may provide interesting information as to whether the intensity of ecotourism in terms of visitor numbers has an impact on the parameters being investigated. Dassen Island on the other hand is completely uninhabited and is not open to tourism in any form. The penguin colony on the island is only occasionally visited by researchers, so including it in a future study would provide an even lower disturbance comparison than the Robben Island colony does.

Incorporating all these factors and additional colonies with more extreme levels of human disturbance for comparison would enable a more in-depth look at how exactly ecotourism is impacting the colonies in question, and provide more information with which to inform management at the ecotourism destinations.

4.4 Conclusion

Ecotourism is growing and will continue to do so as people continue to seek out more environmentally friendly, nature based experiences (Sharpley 2006). While the results from

this thesis suggest that there is a possibility that ecotourism may be having an impact upon African penguin breeding success and chick condition at the Stony Point colony, such an assessment is complicated due to the number of other factors that may be having an effect on the parameters reported in this study. The interactions between penguins, humans and the environment are complex and involve a number of factors. For this reason, multi-disciplinary studies are vital in order to identify any causes, and this study highlights the importance of this. In order to fully understand the impact that ecotourism and the associated human visitation has upon African colonies, further research is required. It is recommended that these studies take place over a number of years, and consider including other colonies with different levels of human visitation, as well as data on predation, nest type, tourist visitor numbers, and food availability in order to identify exactly where the problem lies. This will enable managing authorities to effectively address any issues associated with ecotourism and the associated human presence, resulting in positive outcomes for both the tourism industry and the endangered African penguin.

Chapter 5 - References

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Appendix I – Conservation Biology Style Guide for Authors

This thesis was referenced in the style of the Conservation Biology journal. The style guide for authors containing this information can be found at the link below.

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