DESERT ROSE: PORTAL SUBMISSION DOCUMENT LIST

SUPPORTING DOCUMENTS SECTION

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APPENDIX N:

BIOPHYSICAL ASSESSMENT

APPENDIX N:

BIOPHYSICAL ASSESSMENT

DOCUMENT LIST

17.1.

BIOPHYSICAL ASSESSMENT REPORT

BIOPHYSICAL ASSESSMENT (VERTEBRATE FAUNA & FLORA): DESERT ROSE DEVELOPMENT (Swakopmund/Walvis Bay area) [Baseline/Scoping & Rapid Site Visit]

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1 INTRODUCTION

A desktop study (i.e. literature review) was conducted between 24 and 26 June 2014 on the vertebrate fauna (e.g. reptiles, amphibians, mammals and birds) expected to occur in the general coastal area between Swakopmund and Walvis Bay. A rapid site assessment was conducted between 29 June and 2 July 2014 to determine the actual vertebrate fauna and flora on site and which potentially could be affected by the proposed Desert Rose urban developments.

This literature review was to determine the actual as well as potential vertebrate fauna associated with the general area commonly referred to as the Southern Namib or Southern Desert (Giess 1971, Mendelsohn *et al.* 2002, Van der Merwe 1983). This area is bordered inland by the Central Namib or Central Desert (Giess 1971, Mendelsohn *et al.* 2002). Climatically the coastal area is referred to as Cool Desert with a high occurrence of fog (van der Merwe 1983). The Namib Desert Biome makes up a large proportion (32%) of the land area of Namibia with parks in this biome making up 69% of the protected area network or 29.7% of the biome (Barnard 1998). Four of 14 desert vegetation types are adequately protected with up to 94% representation in the protected area network in Namibia (Barnard 1998). With the exception of municipal land, the area falls within the recently proclaimed Dorob National Park. No communal and freehold conservancies are located in the general area with the closest communal conservancy being the ≠Gaingu Conservancy in the Spitzkoppe area approximately 100 km to the northeast (Mendelsohn *et al.* 2002, NACSO 2010).

Two important coastal wetlands – i.e. Walvis Bay Wetlands and Sandwich Harbour – both Ramsar sites, occur in the area. According to Curtis and Barnard (1998) the entire coast and the Walvis Bay lagoon as a coastal wetland, are viewed as sites with special ecological importance in Namibia. The known distinctive values along the coastline are its biotic richness (arachnids, birds and lichens) with the Walvis Bay lagoon's importance being its biotic richness and migrant shorebirds as well as being the most important Ramsar site in Namibia. The Ramsar site covers 12,600 ha with regular counts of birds varying between 37,000 and well over 100,000 individuals, albeit mainly migratory species (Kolberg n.d.). The Walvis Bay wetland is considered the most important coastal wetland in southern Africa and one of the top 3 in Africa (Shaw *et al.* 2004). The Sandwich Harbour Ramsar site covers 16,500 ha and falls within the Namib-Naukluft Park and enjoys full protection (Kolberg n.d.). This area is a centre of concentration of migratory shorebirds, waders and flamingos regularly supporting over 142,000 and 50,000 birds during summer and winter, respectively (Kolberg n.d.).

The area is bordered by the Kuiseb River to the south (Walvis Bay area) and the Swakop River to the north (Swakopmund area) with catchment areas of 15,500 km² and 30,100 km², respectively with common riparian species including Ana tree, Tamarix, Camelthorn, Salvadora, Fig, Euclea, !Nara and Mesquite (Jacobson *et al.* 1995).

The central coastal region, and the Swakopmund/Walvis Bay area in particular, is regarded as "relatively low" in overall (all terrestrial species) diversity (Mendelsohn *et al.* 2002). Overall terrestrial endemism in the area on the other hand is "moderate to high" (Mendelsohn *et al.* 2002).

The overall diversity and abundance of large herbivorous mammals (big game) is viewed as "low to medium" with 1-2 species while overall diversity of large carnivorous mammals (large predators) is determined at 4 species with brown hyena being the most important with "medium" densities expected in the area (Mendelsohn *et al.* 2002).

It is estimated that at least 54 reptile, 7 amphibian, 43 mammal and 182 bird species (breeding residents) are known to or expected to occur in the general/immediate

Swakopmund/ Walvis Bay area of which a high proportion are endemics (e.g. reptiles with 50%).

According to Maggs (1998) there are approximately 4344 higher plant species with the most species being within the grasses (422), composites (Asteraceae) (385), legumes (Fabaceae) (377) and fygies (Mesembryanthemaceae) (177), recorded from Namibia. Total species richness depends on further collecting and taxonomic revisions. High species richness is found in the Okavango, Otavi/Karsveld, Kaokoveld, southern Namib and Central Highland (Windhoek Mountains) areas. Endemic species – approximately 687 species in total – are manly associated with the Kaokoveld (northwestern) and the succulent Karoo (southwestern) Namibia. The major threats to the floral diversity in Namibia are:
1). Conversion of the land to agriculture (with associated problems) and,
2). poorly considered development (Maggs 1998, Mendelsohn *et al.* 2002).

The vegetation in the Desert Biome is characterised by a dominance of therophytes which persist in the form of seeds during unfavourable conditions (Lovegrove 1999). According to Mendelsohn *et al.* (2002) the dominant vegetation structure in the Southern Desert is grassland and dwarf shrubland. These Namib grasslands – mainly annual species – are very sparse, but nevertheless still dominate the little vegetation that grows there. The average plant production is extremely low with 0-5% variation in green vegetation biomass (Mendelsohn *et al.* 2002). The overall plant diversity (all species) in the general Walvis Bay/Swakopmund area is estimated as <50 species (Mendelsohn *et al.* 2002). These estimates are limited to "higher" plants as information regarding "lower" plants is sparse. Burke (2003) estimates that over 400 species – 10% of the flora of Namibia – occur in the central Namib and although it has not been identified as a centre of endemism, it is dominated by endemics such as *Arthraerua leubnitziae*. The greatest variants affecting the diversity of plants are habitat and climate with the highest plant diversity generally associated with high rainfall areas.

Pockets of high diversity are found throughout Namibia in "unique" habitat – often transition zones – e.g. mountains, inselbergs, etc. Plant endemism is viewed as "medium" – with between 1-15 endemics expected from the general area (Mendelsohn *et al.* 2002). Furthermore, Mendelsohn *et al.* (2002) views the grazing and browse as virtually nonexistent in the general area. The tourism potential of this area is viewed as moderate (Mendelsohn *et al.* 2002, van der Merwe 1983).

It is estimated that up to 39 species of larger trees and shrubs and up to 48 grasses are known to or expected to occur in the general/immediate Swakopmund/Walvis Bay area.

2 METHODS

2.1 Literature Review

A comprehensive literature review on the existing as well as "recent" relevant publications pertinent to the topic was conducted prior to the fieldwork. This review included vertebrate fauna (amphibians, mammals, reptiles and birds) and flora (larger trees/shrubs and grasses, etc.) known or expected to occur in the general/immediate Swakopmund/Walvis Bay area. The focus was on unique species – i.e. rare, threatened & endangered (RT&E), protected, endemic, etc. species as determined by the International and Namibian legal status for such species. A list of the references consulted can be viewed in the Reference section (Page 44).

2.2 Field survey

A site visit was conducted to the proposed development area between 29 June and 2 July 2014 to familiarise myself with the local environment as well as conduct a rapid survey on the vertebrate fauna and flora actually occurring on site.

Fieldwork included the following:

- Small mammal transects – small mammal diversity;
- Larger mammal presence determined;
- Reptile & amphibian transects (diurnal & nocturnal) – reptile & amphibian diversity;
- Bird transects – avian diversity; and
- Flora transects – plant diversity in the area.

Methods:

- Small mammal trapping was conducted (i.e. active trapping) using collapsible Sherman traps. Small mammals caught were identified *in situ*, photographed, measured (when applicable to facilitate identification) and released unharmed at the site of capture.

- Larger mammal presence was determined by direct observations including other signs – e.g. tracks, scats, carcasses, burrows, scrapes, etc.

- Reptile & amphibian transects were conducted during daylight hours to determine diurnal diversity. As the night time temperatures were below 16°C no nocturnal searches were conducted as most reptiles are inactive at these temperatures. Reptiles were caught using an active capture technique ('reptile noosing') and identified *in situ*, photographed, measured (when applicable to facilitate identification) and released unharmed at the site of capture.

- Bird transects (on foot & by vehicle) were conducted during daylight hours using binoculars to ID and confirm species.

- Flora transects to determine species composition – all species – was conducted throughout the area. Focus was on the identification of unique species in the proposed development area.

  [Transects – lengths & direction – varied according to the terrain, and did not follow straight lines]

3 RESULTS

3.1 Reptile Diversity

Table 1 indicates the reptile diversity known and/or expected to occur in the general area between Swakopmund and Walvis Bay as well as species actually confirmed during the fieldwork (√*) or using the authors previous sightings (√[1,2,3]) from the area:

Table 1. Reptile diversity known and/or expected to occur in the general area – i.e. Swakopmund/Walvis Bay area – and species confirmed during the fieldwork and/or the author's previous records (√[1,2,3]) from the area.

Species: Scientific name	Species: Common name	Species Confirmed	Namibian conservation and legal status	International status		
				SARDB	IUCN	CITES
TURTLES AND TERRAPINS						

Pelomedusa subrufa	Marsh/Helmeted Terrapin		Secure			
SNAKES						
Thread Snakes						
Leptotyphlops occidentalis	Western Thread Snake		Endemic; Secure	P		
Leptotyphlops labialis	Damara Thread Snake		Endemic; Secure			
Burrowing Snakes						
Xenocalamus bicolour bicolor	Bicoloured Quill-snouted Snake		Secure			
Typical Snakes						
Lamprophis fuliginosus	Brown House Snake		Secure			
Lycophidion capense	Cape Wolf Snake		Secure			
Pseudaspis cana	Mole Snake		Secure			
Dipsina multimaculata	Dwarf Beaked Snake	√[1]	Endemic; Secure			
Psammophis trigrammus	Western Sand Snake		Endemic; Secure			
Psammophis notostictus	Karoo Sand Snake		Secure			
Psammophis namibensis	Namib Sand Snake	√[1,2,3]	Secure			
Dasypeltis scabra	Common/Rhombic Egg Eater		Secure			
Aspidelaps lubricus infuscatus	Coral Snake		Secure			
Aspidelaps scutatus scutatus	Shield-nose Snake		Secure			
Naya nigricincta	Black-necked Spitting Cobra	√[1,3]	Endemic; Secure			
Bitis arietans	Puff Adder	√[1]	Secure			
Bitis caudalis	Horned Adder	√[1,2,3]	Secure			
Bitis peringueyi	Péringuey's Adder	√*, √[1]	Endemic; Secure		LC	
LIZARDS						
Skinks						
Typhlosaurus braini	Brains's Blind Legless Skink		Endemic; Secure			
Typhlacontias brevipes	FitzSimmons' Burrowing Skink	√*, √[1]	Endemic; Secure			
Trachylepis occidentalis	Western Three-striped Skink		Secure			
Trachylepis striata wahlbergi	Striped Skink		Secure			
Trachylepis sulcata	Western Rock Skink	√[1]	Secure			
Trachylepis variegata variegata	Variegated Skink		Secure			
Old World Lizards						
Heliobolus lugubris	Bushveld Lizard		Secure			
Meroles anchietae	Shovel-snouted Lizard	√[1]	Secure			
Meroles cuneirostris	Wedge-snouted Desert Lizard	√[1,3]	Endemic; Secure			
Meroles micropholidotus	Small-scaled Desert Lizard		Endemic; Rare?			
Meroles reticulatus	Reticulated Desert Lizard	√*, √[1,2]	Endemic; Secure			
Meroles suborbitalis	Spotted Desert Lizard	√[1,3]	Secure			
Pedioplanis breviceps	Short-headed Sand Lizard	√[1]	Endemic; Secure			
Pedioplanis namaquensis	Namaqua Sand Lizard	√[1]	Secure			
Pedioplanis inornata	Plain Sand Lizard	√[1,2,3]	Endemic; Secure			
Plated Lizards						
Cordylosaurus subtessellatus	Dwarf Plated Lizard		Endemic; Secure		LC	
Monitors						
Varanus albigularis	Rock Monitor		Vulnerable; Peripheral Protected Game	V		C2
Agama						
Agama planiceps	Namibian Rock Agama		Secure			

Chameleons					
Bradypodion pumilum	Cape Dwarf Chameleon	√[1]	Introduced alien Secure		C2
Chamaeleo namaquensis	Namaqua Chameleon	√[1,2,3]	Secure	LC	C2
Geckos					
Afroedura africana africana	African Flat Gecko		Endemic; Rare?		
Chondrodactylus angulifer namibensis	Giant Ground Gecko	√[1,3]	Secure		
Narudasia festiva	Festive Gecko		Endemic; Secure		
Pachydactylus bicolour	Velvety Thick-toed Gecko	√[1,3]	Endemic; Secure		
Pachydactylus kockii	Koch's Thick-toed Gecko	√[3]	Endemic; Secure		
Pachydactylus turneri	Turner's Thick-toed Gecko	√[1]	Secure		
Pachydactylus scherzi	Schertz's Thick-toed Gecko		Endemic; Secure		
Pachydactylus rugosus rugosus	Rough Thick-toed Gecko		Endemic; Secure		
Pachydactylus weberi werneri	Weber's Thick-toed Gecko		Endemic; Secure		
Palmatogecko rangei	Wed-footed Gecko	√[1]	Endemic; Secure		
Ptenopus carpi	Carp's Barking Gecko	√[1,3]	Endemic; Secure		
Ptenopus garrulus maculatus	Common Barking Gecko	√[1,3]	Secure		
Ptenopus kocki	Kock's Barking Gecko	√[1]	Endemic; Secure	LC	
Rhoptropus afer	Common Namib Day Gecko	√[1,2,3]	Endemic; Secure		
Rhoptropus boultoni	Boulton's Namib Day Gecko	√[1]	Endemic; Secure		
Rhoptropus bradfieldi	Bradfield's Namib Day Gecko		Endemic; Secure		

Namibian conservation and legal status according to the Nature Conservation Ordinance No 4 of 1975 (Griffin 2003)
Endemic – includes Southern African Status (Branch 1998)
SARDB (2004): V – Vulnerable; P – Peripheral (South African Red Data Book)
IUCN (2014): LC – Least Concern (Most reptiles not yet assessed by the IUCN Red List)
CITES: Appendix 2 species
√[1] – Cunningham (2011a); √[2] – Cunningham (2010a); √[3] – Cunningham (2010b)
Source for literature review: Alexander and Marais (2007), Branch (1998), Branch (2008), Boycott and Bourquin 2000, Broadley (1983), Buys and Buys (1983), Cunningham (2006, 2010a,b & 2011), Griffin (1998a), Griffin (2003), Hebbard (n.d.), Marais (1992), Tolley and Burger (2007)

Approximately 261 species of reptiles are known or expected to occur in Namibia thus supporting approximately 30% of the continents species diversity (Griffin 1998a). At least 22% or 55 species of Namibian lizards are classified as endemic. The occurrence of reptiles of "conservation concern" includes about 67% of Namibian reptiles (Griffin 1998a). Emergency grazing and large scale mineral extraction in critical habitats are some of the biggest problems facing reptiles in Namibia (Griffin 1998a). The overall reptile diversity and endemism in the Swakopmund/Walvis Bay area is estimated at between 31-50 species and 17-24 species, respectively (Mendelsohn *et al.* 2002). Griffin (1998a) presents figures of between 1-20 and 9-10 for endemic lizards and snakes, respectively, from the general central coastal part of Namibia.

According to the literature review at least 54 species of reptiles are expected to occur in the general Swakopmund/Walvis Bay area with 27 species being endemic – i.e. 50% endemic, 1 species (*Varanus albigularis*) vulnerable, 2 species rare and insufficiently known while 6 species have some form of international conservation status (IUCN and CITES). These consist of at least 17 snakes (2 thread snakes, 1 burrowing snake, 14 typical snakes) of which 6 species (35%) are endemic, 1 terrapin, 16 lizards (50% endemic), 1 monitor, 1 agama, 2 chameleons (although the Cape dwarf chameleon is endemic to South Africa it was introduced to gardens in the Walvis Bay area and thus does not occur there naturally – i.e. alien) and 16 geckos (81% endemic).

Lizards (16 species with 8 species being endemic) and Gecko's (16 species with 13 species being endemic) are the most important group of reptiles expected from the Swakopmund/ Walvis Bay area. Namibia with approximately 129 species of lizards (Lacertilia) has one of the continents richest lizard fauna (Griffin 1998a). Geckos expected and/or known to occur in the Swakopmund/Walvis Bay area have the highest occurrence of endemics (81%) of all the reptiles in this area. Griffin (1998a) confirms the importance of the gecko fauna in Namibia. Both thread snakes expected from the area are classified as endemic.

The endemic species observed and/or confirmed throughout the general area and viewed as the most important are *Bitis peringueyi* (Péringuey's adder), *Typhlacontias brevipes* (FitzSimmons' burrowing skink) and various *Meroles* species. All these species are mainly associated with pockets of vegetation throughout the area and susceptible to local disturbances (Figure 1).

Figure 1. *Brownanthus kuntzei* and *Zygophyllum clavatum* hummocks serve as habitat for various vertebrate fauna.

Reptiles encountered during the fieldwork at the proposed Desert Rose Development area:

At least 27 species of reptiles were confirmed from the general area, either through direct observations during rapid site visit (i.e. 3 species) or as confirmed sightings using the author's previous records from the general area (i.e. 24 species – See Cunningham 2011a; Cunningham 2010a and Cunningham 2010b). Of these species, 14 species are classified as endemic (all secure); 1 species classified as an invasive alien species; 3 species classified as least concern by the IUCN (2014) and 1 species classified as a CITES Appendix 2 species (Branch 1998, Griffin 2003, IUCN 2014). Most reptiles have not yet been assessed by the IUCN Red List (IUCN 2014).

The 3 species actually encountered during the rapid site visit included:

Bitis peringueyi (Péringuey's adder);
Meroles reticulatus (Reticulated desert lizard); and

Typhlacontias brevipes (FitzSimmons' burrowing skink).

***Bitis peringueyi* (Péringuey's adder):**
One specimen was encountered, partially submerged, at the base of a *Brownanthus kuntzei* dune hummock (Figure 2). This species is classified as endemic and secure (90% of the taxon's range occurs in Namibia with extralimital range to south-western Angola) in Namibia (Griffin 2003) and as least concern by the IUCN (2014).

Although *B. peringueyi* is usually associated with the dune belt area – e.g. eastern side of the Swakopmund-Walvis Bay road viewed as "typical" habitat – they are found where fine wind-blown sand accumulates (Branch 1998). Their distribution, although disjunct – i.e. northern Namib population is separated from the central/southern population by approximately 290 km between Torra Bay and Swakopmund – occurs from the Kunene River in the north to Lűderitz in the south (Griffin 2003).

This species is not exclusively associated with the proposed Desert Rose development area.

Figure 2. *Bitis peringueyi* (Péringuey's adder) observed submerged in sandy substrate at the base of a vegetated dune hummock.

***Meroles reticulatus* (Reticulated desert lizard):**
Three specimen were encountered in vegetated dune hummock areas although tracks were observed more often, but overall cool (<16°C) weather conditions limited their aboveground activity (Figure 3). This species is classified as endemic and secure (80% of the taxon's range occurs in Namibia with extralimital range to south-western Angola) in Namibia (Griffin 2003) although not yet assessed by the IUCN (2014).

M. reticulates occurs on sandy substrate in sparsely vegetated coastal desert (Branch 1998) from around the Meob Bay area in the south to the Kunene River in the north with some populations occurring as isolated pockets as well as further inland in suitable habitat (Griffin 2003).

This species is not exclusively associated with the proposed Desert Rose development area.

Figure 3. *Meroles reticulatus* (Reticulated desert lizard) associated with vegetated dune hummock areas in the Desert Rose development area (See low vegetated dune hummocks in the background).

Typhlacontias brevipes **(FitzSimmons' burrowing skink):**
Evidence of *T. brevipes* – i.e. typical "burrow tracks" – was observed in sandy substrate in well vegetated dune hummock areas (Figure 4). This species is classified as endemic and secure (100% of the taxon's range) in Namibia (Griffin 2003) although not yet assessed by the IUCN (2014).

T. brevipes occurs along the coastal Namib from north of Lűderitz to the Kunene River as a fossorial-aeolean sand species usually associated with semi-stable sandy areas where they forage around vegetation leaving characteristic wavy tracks (Branch 1998, Griffin 2003).

This species is not exclusively associated with the proposed Desert Rose development area.

Figure 4. Typical *Typhlacontias brevipes* (FitzSimmons' burrowing skink) tracks observed around vegetated dune hummocks throughout the area.

3.2 Amphibian Diversity

Table 2 indicates the amphibian diversity known and/or expected to occur in the general area between Swakopmund and Walvis Bay.

Table 2. Amphibian diversity known and/or expected to occur in the general area – i.e. Swakopmund/Walvis Bay area.

Species: Scientific name	Species: Common name	Namibian conservation and legal status	International Status: IUCN
Toads			
Poyntonophrynus dombensis	Dombe Toad	Endemic	LC
Poyntonophrynus hoeschi	Hoesch's Toad	Endemic	LC
Amietophrynus poweri	Power's Toad or Western Olive Toad		LC
Rain Frogs			
Breviceps adspersus	Common/Bushveld Rain Frog		LC
Rubber Frog			
Phrynomantis annectens	Marbled Rubber Frog	Endemic	LC
Bull and Sand Frogs			
Tomopterna tandyi	Tandy's Sand Frog		LC
Platannas			
Xenopus laevis	Common Platanna		LC

IUCN (2014): LC – Least Concern
Source for literature review: Carruthers (2001), Channing (2001), Channing and Griffin (1993), Du Preez and Carruthers (2009), Passmore and Carruthers (1995)

Amphibians are declining throughout the world due to various factors of which much has been ascribed to habitat destruction. Basic species lists for various habitats are not always available with Namibia being no exception in this regard while the basic ecology of most species is also unknown. Approximately 4,000 species of amphibians are known worldwide with just over 200 species known from southern Africa and at least 57 species expected to occur in Namibia. Griffin (1998b) puts this figure at 50 recorded species and a final species richness of approximately 65 species, 6 of which are endemic to Namibia. This "low" number of amphibians from Namibia is not only as a result of the generally marginal desert habitat, but also due to Namibia being under studied and under collected. Most amphibians require water to breed and are therefore associated with the permanent water bodies, mainly in northeast Namibia.

The dry sandy coastal desert (Namib) and saline coastal areas are poor habitat for amphibians (Cunningham & Jankowitz 2010). Although the ephemeral Kuiseb and Swakop Rivers reach the sea in the Walvis Bay and Swakopmund areas, they seldom flow with temporary freshwater pools being rare close to the coast. The ephemeral Tumas River, located between the Kuiseb and Swakop Rivers, flows even more sporadically and is effectively blocked by the high dunes in the area (i.e. east of the dune belt area). Other water bodies in the area (except for leakages associated with various pipelines) are generally saline of nature and not suitable habitat for amphibians. Overall, the saline coastal habitats are marginal for amphibians. According to Mendelsohn *et al.* (2002), the overall frog diversity in the Swakopmund/Walvis Bay area is estimated at between 1-3 species. Griffin (1998b) puts the species richness in the general area between 1-2 species.

According to the literature review, up to 7 species of amphibians can occur in suitable habitat in the general Swakopmund/Walvis Bay area. The area is under represented, with 3 toads and 1 species each for rain, rubber and sand frog and platanna known and/or expected (i.e. potentially could be found in the area) to occur in the area. Three species (43%) namely

Poyntonophrynus dombensis, *Poyntonophrynus hoeschi* and *Phrynomantis annectens* are classified as endemic to Namibia (Griffin 1998b) while all 7 species are classified as "least concern" by the IUCN (IUCN 2014).

The area is extremely marginal with very little rainfall (<50mm annual average) generally occurring in the area and being highly variable (>100% coefficient of variation) and sporadic of nature (Mendelsohn *et al.* 2002). However, the area undoubtedly has suitable, albeit temporary of nature, amphibian habitat during the rainy season (or where rainfall does occur) when pools could collect in the Kuiseb, Swakop and Tumas Rivers and their tributaries and more especially in rocky hollows, further inland. The Kuiseb and Swakop Rivers flooded for lengthy periods during the unusually high 2011 rainy season. This could have resulted in amphibians being transported into the area which otherwise remains generally poor habitat.

No amphibians were identified during the fieldwork nor other surveys conducted by the author in the general area (Cunningham 2010a,b & 2011).

The amphibians expected in the general area are however not expected to be exclusively associated with the area with the 3 endemics that could potentially occur in the area occurring widespread throughout Namibia and not specifically associated with the proposed development site.

3.3 Mammal Diversity

Table 3 indicates the mammal diversity known and/or expected to occur in the general area between Swakopmund and Walvis Bay as well as species actually confirmed during the fieldwork (√*) or using the authors previous sightings (√[1,2,3]) from the area:

Table 3. Mammal diversity known and/or expected to occur in the general area – i.e. Swakopmund/Walvis Bay area – and species confirmed during the fieldwork and/or the author's previous records (√[1,2,3]) from the area.

Species: Scientific name	Species: Common name	Species Confirmed	Namibian conservation and legal status	International Status		
				SARDB	IUCN	CITES
Moles						
Eremitalpa granti	Grant's Golden Mole	√[1]	Endemic; Secure	V	LC	
Elephant Shrews						
Macroscelides proboscideus flavicaudatus	Round-eared Elephant-shrew	√[1]	Endemic; Secure		LC	
Bats						
Lissonycteris angolensis	*Angolan Soft-furred Fruit Bat		Not listed		LC	
Tadarida aegyptiaca	Egyptian Free-tailed Bat		Secure		LC	
Cistugo seabrai	Namibian Wing-gland Bat		Endemic; Rare	V	LC	
Laephotis namibensis	Namib Long-eared Bat		Endemic; Insufficiently known		LC	
Nycteris thebaica	Common Slit-faced Bat		Secure		LC	
Rhinolophus clivosus	Geoffroy's Horseshoe Bat		Secure	NT	LC	
Rhinilophus darlingi	Darling's Horseshoe Bat		Secure	NT		
Rhinolophus capensis	*Cape Horseshoe Bat		Secure	NT	LC	
Taphozous mauritianus	*Mauritanian Tomb Bat		Secure		LC	
Chaerephon ansorgei	*Ansorge's Free-tailed Bat		Not listed		LC	
Sauromys petrophilus	Roberts's Flat-headed Bat		Secure		LC	
Miniopterus natalensis	Natal Long-fingered Bat		Secure	NT	LC	
Eptesicus hottentotus	Long-tailed Serotine		Secure		LC	
Neoromicia zuluensis	*Zulu Serotine		Secure		LC	

Pipistrellus rueppellii	*Rüppell's Pipistrelle		Insufficiently known; Peripheral		LC	
Hares and Rabbits						
Lepus capensis	Cape Hare	√[1]	Secure			
Rodents					LC	
Rats and Mice						
Parotomys littledalei namibensis	Littledale's Whistling Rat		Endemic; Secure	NT	LC	
Rhabdomys pumilio	Striped Mouse	√[1,2]	Secure		LC	
Mus musculus	House Mouse	√[1]	Invasive alien		LC	
Aethomys chrysophilus	Red Veld Rat		Secure		LC	
Aethomys namaquensis	Namaqua Rock Mouse	√[1]	Secure		LC	
Rattus rattus	House Rat	√[1]	Invasive alien		LC	
Rattus norvegicus	Brown Rat		Invasive alien		LC	
Desmodillus auricularis	Short-tailed Gerbil		Secure		LC	
Gerbillurus paeba	Hairy-footed Gerbil		Endemic; Insufficiently known		LC	
Gerbillurus tytonis	Dune Hairy-footed Gerbil	√*,√[1,2]	Endemic; Secure		LC	
Gerbillurus setzeri	Setzer's Hairy-footed Gerbil or Namib Brush-tailed Gerbil		Endemic		LC	
Petromyscus collinus	Pygmy Rock Mouse		Endemic; Secure		LC	
Mastomys coucha	Southern Multimammate Mouse		Secure		LC	
Petromys typicus	Dassie Rat		Endemic; Secure	NT		
Carnivores						
Hyaena brunnea	Brown Hyena	√*,√[1,2]	Insufficiently known; Vulnerable? Peripheral; Protected game	NT	NT	
Crocuta crocuta	Spotted Hyena		Secure? Peripheral	NT	LC	
Felis silvestris	African Wild Cat	√[1]	Vulnerable		LC	C2
Vulpes chama	Cape Fox	√[1]	Vulnerable?		LC	
Canis mesomelas	Black-backed Jackal	√*,√[1,2]	Secure; Problem animal		LC	
Otocyon megalotis	Bat-eared Fox		Vulnerable?; Peripheral		LC	
Ictonyx striatus	Striped Polecat		Secure		LC	
Suricata suricatta marjoriae	Suricate	√*,√[1]	Endemic; Secure		LC	
Antelopes						
Sylvicapra grimmia	Common Duiker		Secure		LC	
Antidorcas marsupialis	Springbok	√[1,2]	Secure; Huntable game		LC	
Oryx gazella	Gemsbok	√[1]	Secure; Huntable game		LC	

SARDB (2004): NT – Near Threatened; V – Vulnerable
IUCN (2014): NT – Near Threatened; LC – Least Concern
CITES: Appendix 2 species
* Unconfirmed bat species although potentially could occur in area according to habitat modelling (Monadjem *et al.* 2010)
√[1] – Cunningham (2011a); √[2] – Cunningham (2010a); √[3] – Cunningham (2010b)
Source for literature review: Cunningham (2010a,b & 2011), De Graaff (1981), Griffin (2005), Estes (1995), Joubert and Mostert (1975), Monadjem *et al.* (2010), Skinner and Smithers (1990), Skinner and Chimimba (2005) and Taylor (2000)

Namibia is well endowed with mammal diversity with at least 250 species occurring in the country. These include the well known big and hairy as well as a legion of smaller and lesser-known species. Currently 14 mammal species are considered endemic to Namibia of which 11 species are rodents and small carnivores of which very little is known. Most endemic mammals are associated with the Namib and escarpment with 60% of these rock-dwelling (Griffin 1998c). According to Griffin (1998c) the endemic mammal fauna is best characterized by the endemic rodent family *Petromuridae* (Dassie rat) and the rodent genera *Gerbillurus* and *Petromyscus*. The overall mammal diversity in the Walvis Bay area is estimated at between 16-30 species with 3-4 species being endemic to the area (Mendelsohn *et al.* 2002).

Overall terrestrial diversity – all species – is classified as "low" in the western coastal parts of Namibia (Mendelsohn *et al.* 2002). The overall diversity (1-2 species) and abundance of large herbivorous mammals is low in the Walvis Bay area with springbok and gemsbok having the highest density of the larger species (Mendelsohn *et al.* 2002). The overall abundance and diversity of large carnivorous mammals is relatively high (4 species) in the Walvis Bay area with brown hyena having the highest density of the larger species (Mendelsohn *et al.* 2002).

According to the literature review, up to 43 species of mammals are known and/or expected to occur in the general Swakopmund/Walvis Bay area of which 11 species (25.6%) are classified as endemic. According to the Namibian legislation 1 species is classified as rare, 4 species as vulnerable, 4 species as insufficiently known, 3 species as invasive aliens, 2 species as huntable game, 1 species as problem animal while 2 species (both bats) are not listed. Eleven species are listed with various international conservation statuses of which 2 species are classified as vulnerable (*Eremitalpa granti and Cistugo seabrai*) and 8 species as near threatened by the SARDB (SARDB 2004). The IUCN (IUCN 2014) classifies 1 species as near threatened (*Hyaena brunnea*) (all other species classified as least concern) while 1 species is classified as a CITES Appendix II species.

The House Mouse (*Mus musculus*) and the rats *Rattus rattus* and *Rattus norvegicus* are viewed as invasive aliens to the area. *Mus musculus* are generally known as casual pests and not viewed as problematic although they are known carriers of "plague" and can cause economic losses. The biggest problem with the *Rattus* species is economic losses and garden pests along the coast (Griffin 2003). Mammal species probably underrepresented in Table 3 for the general area are the bats as this group has not been well documented from the arid western parts of Namibia.

At least 40.5% and 35.7% of the mammalian fauna that occur or are expected to occur in the Swakopmund/Walvis Bay area are represented by rodents (17 species) and bats (15 species) of which 9 species (21.4%) are endemic to Namibia. Some species such as *Petromys typicus* are not expected to occur in the area as they typically favour rocky habitat and are known to occur further inland in favourable habitat – e.g. Swakop River rocky areas. Habitats often not valued as unique are the vegetated dune hummocks and seemingly barren gravel plains along the coast. Habitat alteration and overutilization are the two primary processes threatening most mammals (Griffin 1998c).

The most important mammal species known and/or expected to occur in the general area are viewed as the little known bats – i.e. *Cistugo seabrai* and *Laephotis namibensis* – and the carnivores *Hyaena brunnea* (brown hyena) and *Felis silvestris* (African wild cat). Both carnivores are shy and elusive and tend to avoid disturbed areas. *H. brunnea* are nowhere common throughout their range while *F. silvestris* furthermore faces genetic pollution issues with feral cats close to human settlements. Although most of the species of conservation concern are viewed as "secure", overall habitat alteration and overutilization are the two primary processes threatening most mammals in Namibia (Griffin 1998c).

Many species included in Table 3 – i.e. expected to occur in the general area – do not necessarily occur along the coast or expected to occur in the proposed Desert Rose development area – e.g. spotted hyena, duiker and gemsbok. Springbok occur in the general area although usually east of the dune belt.

Other species serendipitously observed in the general area although not indicated in Table 3 include aardvark (Protected Game), warthog (Huntable Game) and kudu (Huntable Game) (Cunningham 2011a). However, these species probably indicate vagrants having followed the various drainage lines into the area and are not permanently associated with the area.

However, none of the important mammal species are exclusively associated with the proposed development area.

Mammals encountered during the fieldwork at the proposed Desert Rose Development area:

At least 15 species of mammals were confirmed from the general area, either through direct observations (i.e. 3 species) or as confirmed sightings using the author's previous records from the general area (i.e. 12 species – See Cunningham 2011a; Cunningham 2010a and Cunningham 2010b). Of these species, 4 species are classified as endemic (all secure); 1 species as insufficiently known, 3 species as vulnerable, 2 species as invasive aliens and 2 species as huntable game (Griffin 1998c) while 1 species is classified as near threatened – population decreasing – by the IUCN (2014) and 1 species classified as a CITES Appendix 2 species (Branch 1998, Griffin 2003, IUCN 2014).

The 4 species actually encountered during the fieldwork included:

Gerbillurus tytonis (dune hairy-footed gerbil);
Hyaena brunnea (brown hyena);
Canis mesomelas (black-backed jackal); and
Suricata suricatta marjoriae (suricate).

***Gerbillurus tytonis* (dune hairy-footed gerbil):**
Dune hairy-footed gerbils are common in the vegetated coastal dune hummock areas with tracks and burrows commonly observed. Small mammal trapping confirmed their presence in the area (Figures 5 & 6). This species is classified as endemic and secure (100% of the taxon's range) in Namibia (Griffin 2003) although listed as least concern by the IUCN (2014).

Dune hairy-footed gerbils occur in the central Namib sand sea from Swakopmund to Koichab Pan in the south (Griffin and Coetzee 2005).

This species is not exclusively associated with the proposed Desert Rose development area.

Figure 5. *Gerbillurus tytonis* (dune hairy-footed gerbil) captured in the area.

Figure 6. Sherman small mammal trap set in *Arthraerua leubnitziae* dune hummock.

***Hyaena brunnea* (brown hyena):**
Brown hyena is nowhere common in Namibia although more common in protected and undeveloped coastal areas, especially areas such as the Sperrgebied. A typical brown hyena track was observed where it was seen criss-crossing the area whilst foraging throughout the area (Figure 7). This species is classified as insufficiently known;

vulnerable?; peripheral; protected game (25% of the taxon's range occurs in Namibia with extralimital range to Angola, Botswana and South Africa) in Namibia (Griffin and Coetzee 2005) and listed as near threatened with populations decreasing by the IUCN (2014).

Brown hyena occurs throughout Namibia except the Zambezi Region and the south-eastern quarter of the country (Griffin and Coetzee 2005). They are not common in the developed coastal area between Swakopmund and Walvis Bay, with the tracks observed likely to be that of a visitor rather than a resident animal. The area is not viewed as core habitat for brown hyena with only occasional references from the guano island and around Walvis Bay and one carcass as beach flotsam in the general area (I. Wiesel *Pers. com.*).

This species is not exclusively associated with the proposed Desert Rose development area.

Figure 7. Typical brown hyena (*Hyaena brunnea*) tracks – large fore print and smaller hind print – observed passing through the Desert Rose area.

***Canis mesomelas* (black-backed jackal):**
Black-backed jackals are common throughout Namibia except the Zambezi Region and northern Kavango. Numerous tracks, faeces and evidence of scavenging were observed throughout the proposed Desert Rose development area (Figure 8). This species is classified as a problem animal (secure) (25% of the taxon's range occurs in Namibia with extralimital range to Angola, Botswana and South Africa) in Namibia (Griffin and Coetzee 2005) and listed as least concern by the IUCN (2014).

Black-backed jackals are common in the developed coastal area between Swakopmund and Walvis Bay and adapt well to various human developments from which they often benefit – i.e. human related waste is an added source of food.

This species is not exclusively associated with the proposed Desert Rose development area.

Figure 8. Cape cormorant (*Phalacrocorax capensis*) carcass scavenged by black-backed jackal in area.

Suricata suricatta marjoriae **(suricate):**
Suricate – *S. s. marjoriae* – occur in the central and northern Namib and pro-Namib areas. A few tracks were observed in the old borrow pit area with suitable rocky habitat typically used for burrow purposes (Figure 9). This species is classified as endemic and secure (100% of the taxon's range) in Namibia (Griffin and Coetzee 2005) and listed as least concern by the IUCN (2014).

Although not common in the developed coastal area between Swakopmund and Walvis Bay, they are known to occur in the general area, especially east of the dune belt. The tracks confirm a small population inhabiting the proposed development area.

This species is not exclusively associated with the proposed Desert Rose development area.

Figure 9. *Suricata suricatta marjoriae* (suricate) tracks observed in the area.

3.4 Avian Diversity

Table 4 indicates the bird diversity known and/or expected to occur in the general area between Swakopmund and Walvis Bay as well as species actually confirmed during the fieldwork (√) or using the authors previous records (√*) from the area:

Table 4. Bird diversity known and/or expected to occur in the general area – i.e. Swakopmund/Walvis Bay area – and species confirmed during the fieldwork (√) and/or the author's previous records (√* - e.g. Cunningham 2010a,b and Cunningham 2011a, etc.) from the area. This table excludes migratory birds (e.g. Petrel, Albatross, Skua, etc.) and species breeding extralimital (e.g. stints, sandpipers, etc.) and rather focuses on birds that are breeding residents or can be found in the area during any time of the year. This would imply that many more birds (e.g. Palaearctic migrants) could occur in the area depending on "favourable" environmental conditions.

Species: Scientific name	Species: Common name	Species Confirmed	Namibian conservation and legal status	International status	
				Southern Africa	IUCN
Struthio camelus	Common Ostrich	√*			
Podiceps cristatus	Great Crested Grebe	√*	CE		
Tachybaptus ruficollis	Little Grebe	√*			
Podiceps nigricollis	Black-necked Grebe	√*			
Pelecanus onocrotalus	Great White Pelican	√	E		
Pelecanus rufescens	Pink-backed Pelican	√*			
Phalacrocorax lucidus	White-breasted Cormorant	√			
Morus capensis	Cape Gannet	√*	SP	Breeding End	V
Phalacrocorax capensis	Cape Cormorant	√		Breeding End	E
Phalacrocorax neglectus	Bank Cormorant	√*	SP	End	E

Phalacrocorax africanus	Reed Cormorant				
Phalacrocorax coronatus	Crowned Cormorant	√*		End	NT
Anhinga melanogaster	Darter				
Ardea cinerea	Grey Heron				
Ardea melanocephala	Black-headed Heron				
Ardea purpurea	Purple Heron				
Egretta garzetta	Little Egret				
Egretta intermedia	Yellow-billed Egret	√			
Egretta alba	Great Egret				
Egretta ardesiaca	Black Egret				
Bubulcus ibis	Cattle Egret				
Ardeola ralloides	Squacco Heron				
Ixobrychus minutes	Little Bittern				
Scopus umbretta	Hamerkop				
Ciconia nigra	Black Stork				
Phoenicopterus ruber	Greater Flamingo	√	V		
Phoenicopterus minor	Lesser Flamingo	√*	V		NT
Dendrocygna viduata	Whitefaced Duck	√*			
Alopochen aegyptiacus	Egyptian Goose	√*			
Anas capensis	Cape Teal	√*			
Anas hottentota	Hottentot Teal	√*			
Anas erythrorhyncha	Redbiled Teal	√*			
Anas smithii	Cape Shoveller	√*			
Netta erythrophthalma	Southern Pochard	√*			
Sagittarius serpentarius	Secretarybird				V
Gyps africanus	White-backed Vulture		NT		
Aegypius tracheliotus	Lappet-faced Vulture		V		
Circaetus pectoralis	Black-chested Snake-Eagle	√*			
Elanus caeruleus	Black-shouldered Kite				
Aquila verreauxii	Verreaux's Eagle				
Aquila rapax	Tawny Eagle		E		
Polemaetus bellicosus	Martial Eagle	√*	E		V
Buteo augur	Augur Buzzard				
Melierax canorus	Southern Pale Chanting Goshawk	√*		N-end	
Falco peregrinus	Peregrine Falcon		NT		
Falco biarmicus	Lanner Falcon	√*			
Falco chicquera	Red-necked Falcon				
Falco rupicolus	Rock Kestrel	√			
Falco rupicoloides	Greater Kestrel	√*			
Francolinus adspersus	Red-billed Francolin				
Trunix sylvatica	Kurrichane Buttonquail				
Porphyrio porphyrio	African Purple Swamphen				
Gallinula chloropus	Common Moorhen	√*			
Fulica cristata	Red-knobbed Coot	√*			
Ardeotis kori	Kori Bustard				NT
Neotis ludwigii	Ludwig's Bustard	√*		N-end	E
Eupodotis rueppellii	Rüppell's Korhaan	√*	End	N-end	
Eupodotis afra	Black Korhaan				
Actophilornis africanus	African Jacana	√*			
Rostratula benghalensis	Painted Snipe				
Haematopus moquini	African Black Oystercatcher	√*	V	End	NT
Charadrius marginatus	White-fronted Plover	√			
Charadrius pallidus	Chestnut-banded Plover	√*	V		NT
Charadrius pecuarius	Kittlitz's Plover	√*			
Charadrius tricollaris	Three-banded Plover	√*			
Vanellus armatus	Blacksmith Lapwing	√*			

Recurvirostra avosetta	Pied Avocet	√*			
Himantopus himantopus	Black-winged Stilt	√*			
Burhinus capensis	Spotted Thick-knee				
Cursorius rufus	Burchell's Courser				
Rhinoptilus africanus	Double-banded Courser				
Larus dominicanus	Kelp Gull	√			
Larus cirrocephalus	Grey-headed Gull	√*			
Larus hartlaubii	Hartlaub's Gull	√		End	
Sterna bergii	Swift Tern	√			
Sterna balaenarum	Damara Tern	√*	End; E	Breeding endemic	NT
Chlidonias hybridus	Whiskered Tern				
Pterocles namaqua	Namaqua Sandgrouse			N-end	
Pterocles bicinctus	Double-banded Sandgrouse			N-end	
Columba guinea	Speckled Pigeon				
Columba livea	Rock Dove	√			
Streptopelia capicola	Cape Turtle Dove				
Streptopelia senegalensis	Laughing Dove	√*			
Oena capensis	Namaqua Dove	√*			
Agapornis roseicollis	Rosy-faced Lovebird	√*	End	N-end	
Corythaixoides concolor	Grey Go-away-bird				
Tyto alba	Barn Owl	√*			
Otus leucotis	Southern White-faced Scops-Owl				
Glaucidium perlatum	Pearl-spotted Owlet				
Bubo africanus	Spotted Eagle Owl	√*			
Bubo lacteus	Giant Eagle Owl				
Caprimulgus tristigma	Freckled Nightjar				
Apus bradfieldi	Bradfield's Swift			N-end	
Colius colius	White-backed Mousebird	√*		End	
Urocolius indicus	Red-faced Mousebird	√*			
Ceryle rudis	Pied Kingfisher				
Merops hirundineus	Swallow-tailed Bee-eater				
Upupa epops	Hoopoe				
Phoeniculus cyanomelas	Scimitar-billed Woodhoopoe				
Tockus monteiri	Monteiro's Hornbill		End		
Tockus nasutus	African Grey Hornbill				
Lybius leucomelas	Pied Barbet				
Dendropicos fuscescens	Cardinal Woodpecker				
Mirafra sabota	Sabota Lark	√*			
Mirafra curvirostris	Long-billed Lark	√*			
Calendulauda erythrochlamys	Dune Lark	√*	End	End	
Chersomanes albofasciata	Spike-heeled Lark	√*		N-end	
Calandrella cinerea	Red-capped Lark	√*			
Alauda starki	Stark's Lark	√*		End	
Ammomanopsis grayi	Gray's Lark	√*	End	N-end	
Certhilauda subcoronata	Karoo Long-billed Lark			End	
Eremopterix verticalis	Grey-backed Sparrowlark			N-end	
Hirundo fuligula	Rock Martin	√*			
Riparia paludicola	Brown-throated Martin				
Dicrurus adsimilis	Fork-tailed Drongo	√*			
Corvus capensis	Cape Crow	√*			
Corvus albus	Pied Crow	√			
Parus cinerascens	Ashy Tit			N-end	
Anthoscopus minutes	Cape Penduline Tit			N-end	
Turdoides bicolour	Pied Babbler				
Pycnonotus nigricans	African Red-eyed Bulbul	√*		N-end	

Monticola brevipes	Short-toed Rock Thrush			
Namibornis herero	Herero Chat		End	N-end
Oenanthe monticola	Mountain Wheatear	√*		N-end
Cercomela familiaris	Familiar Chat	√*		
Cercomela tractrac	Tractrac Chat	√*		N-end
Cercomela schlegelii	Karoo Chat			N-end
Myrmecocichla formicivora	Ant-eating Chat			End
Erythropygia paena	Kalahari Robin			
Parisoma subcaeruleum	Chestnut-vented Tit-Babbler	√*		N-end
Parisoma layardi	Layard's Tit-Babbler			End
Zosterops pallidus	Orange River White-eye			End
Sylvietta rufescens	Long-biled Crombec			
Eremomela icteropygialis	Yellow-bellied Eremomela			
Eremomela gregalis	Karoo Eremomela			
Acrocephalus baeticatus	African Reed-Warbler	√*		
Acrocephalus gracilirostris	Lesser Swamp-Warbler			
Cisticola aridulus	Desert Cisticola			
Cisticola subruficapilla	Grey-backed Cisticola			N-end
Cisticola juncidis	Zitting Cisticola			
Prinia flavicans	Black-chested Prinia	√*		
Melaenornis mariquensis	Marico Flycatcher			N-end
Bradornis infuscatus	Chat Flycatcher			N-end
Muscicapa striata	Spotted Flycatcher			
Batis pririt	Pririt Batis			N-end
Motacilla capensis	Cape Wagtail	√*		
Anthus navaeseelandiae	Richard's Pipit			
Anthus similes	Long-billed Pipit			
Anthus vaalensis	Buffy Pipit			
Tchagra australis	Brown-crowned Tchagra			
Lanius collaris	Common Fiscal	√*		
Laniarius atrococcineus	Crimson-breasted Shrike			N-end
Nilaus afer	Brubru			
Telophorus zeylonus	Bokmakierie	√*		N-end
Creatophora cinerea	Wattled Starling	√*		
Lamprotornis nitens	Cape Glossy Starling	√*		
Onychognathus nabouroup	Pale-winged Starling	√*		N-end
Chalcomitra senegalensis	Scarlet-chested Sunbird			
Nectarinia mariquensis	Marico Sunbird			
Nectarinia fusca	Dusky Sunbird	√*		N-end
Passer domesticus	House Sparrow	√*		
Passer motitensis	Great Sparrow	√*		N-end
Passer melanurus	Cape Sparrow	√*		N-end
Passer griseus	Southern Grey-headed Sparrow	√*		
Sporopipes squamifrons	Scaly-feathered Finch	√*		N-end
Plocepasser mahali	White-browed Sparrow-Weaver			
Philetairus socius	Sociable Weaver			End
Ploceus velatus	Southern Masked Weaver	√*		
Quelea quelea	Red-billed Quelea			
Euplectes orix	Southern Red Bishop			
Estrilda erythronotos	Black-faced Waxbill			
Estrilda astrild	Common Waxbill	√*		
Amadina erythrocephala	Red-headed Finch	√*		N-end
Vidua regia	Shaft-tailed Whydah			
Serinus alario	Black-headed Canary			
Serinus flaviventris	Yellow Canary			N-end
Crithagra atrogulariis	Black-throated Canary	√*		

Serinus albogularis	White-throated Canary	√*	N-end
Emberiza capensis	Cape Bunting	√*	N-end
Emberiza tahapisi	Cinnamon-breasted Bunting		
Emberiza impetuani	Lark-like Bunting	√*	N-end

International status: E – endangered, V – vulnerable, NT – near threatened [All other species classified as least concern or not yet been assessed by the IUCN red list] (IUCN 2014)
Namibian status: CE – critically endangered; E – endangered; NT – near threatened; V – vulnerable; SP – specially protected (Simmons and Brown In press)
Southern African status: E – Endemic, NE – near endemic (Hockey *et al.* 2006)
Source for literature review: Brown *et al.* (1998), Hockey *et al.* (2006), Komen (n.d.), Maclean (1985) and Tarboton (2001)

Although Namibia's avifauna is comparatively sparse compared to the high rainfall equatorial areas elsewhere in Africa, approximately 658 species have already been recorded with a diverse and unique group of arid endemics (Brown *et al.* 1998, Maclean 1985). Fourteen species of birds are endemic or near endemic to Namibia with the majority of Namibian endemics occurring in the savannas (30%) of which ten species occur in a north-south belt of dry savannah in central Namibia (Brown *et al.* 1998). Bird diversity is viewed as medium in the Swakopmund/Walvis Bay area with 111-170 species (this would include migrant species) estimated with at least 1-3 species being endemic to the general area (Mendelsohn *et al.* 2000).

According to the literature review, at least 182 species of terrestrial ["breeding residents"] birds occur and/or could occur in the general area at any time (Hockey *et al.* 2006, Maclean 1985, Tarboton 2001). Although many of the species mentioned in Table 4 do not occur permanently in the Swakopmund/Walvis Bay area they are included as potentially breeding/occurring in the general area – i.e. the 182 species is viewed as an overestimate for the actual Desert Rose development site (e.g. ostrich, etc.). Furthermore, environmental conditions such as "berg winds" ("East weather" – local vernacular) often bring unexpected avian guests to the coastal areas although these are not resident all year (Pers obs). All the migrant species (Walvis Bay and surroundings is world renowned for its Palaearctic migrants) have been excluded here, although the Bay area serves as an important feeding ground for a variety of mainly aquatic species. The Swakopmund/Walvis Bay area is also a thoroughfare area for aquatic species, especially the Palaearctic migrants as well as a known route followed by flamingo's moving between the coast and the Etosha Pans (MME 2010).

Seven of the 14 Namibian endemic bird species (50% of all Namibian endemic species or 4% of the species expected to occur in the area) can or are likely to occur in the general Swakopmund/Walvis Bay area. According to the Namibian conservation and legal status, 1 species is classified as critically endangered, 4 species as endangered, 2 species as near threatened, 5 species as vulnerable and 2 species as specially protected (Simmons and Brown In press). Furthermore, the IUCN (2014) classifies 3 species as endangered, 6 species as near threatened and 3 species as vulnerable. According to the southern African status for birds 3 species are classified as breeding endemics, 12 species as endemic and 34 species near endemic (Hockey *et al.* 2006).

Important bird areas in the vicinity of the proposed Desert Rose development area include the Walvis Bay wetland – considered the most important coastal wetland in southern Africa and one of the top 3 in Africa (Bethune *et al.* 2007) and supports mainly Palaearctic migrants, often comprising up to 88% of the birds – e.g. up to 1% of the global chestnut-banded plover (approximately 2,000 individuals) are expected to occur in the Walvis Bay area (Whitelaw *et al.* 1978). Between 70,000 and 100,000 birds in winter and up to 250,000 in spring are supported by the wetland of between 40-50 species in some places (Bethune *et al.* 2007, Shaw *et al.* 2004). The Namib coast is especially important for 8 species and in terms of global populations it supports >90% of the world's chestnut-banded plovers (*Charadrius pallidus*); 31% of Cape teals (*Anas capensis*); and 26% of African black oystercatchers (*Haematopus moquini*). In terms of African endemic races it supports: >90% of the black-necked grebe (*Podiceps nigricollis gurneyi*); and 33% of the white-fronted plover (*Charadrius m*. m*arginatus*); and in terms of southern African sub-continental populations it supports 31% of pied avocets (*Recurvirosta avocetta*), 13.7% of greater flamingos (*Phoenicopterus roseus*) and 10.3% of lesser flamingos (*Phoenicopterus minor*) (Williams and Simmons 2008a). Furthermore, up to 200,000 Holarctic shorebirds are supported seasonally along the Namibian coast belonging largely to 12 annually occurring species, of which 5 species occur in numbers that form a significant proportion of the southern African flyway populations – e.g. curlew sandpiper (*Calidris ferruginea* 35%); Sanderling (*C. alba* 32%); ruddy turnstone (*Arenaria interpres* 17.5%); grey plover (*Pluvialis squatarola* 7.8%) and red knot (*Calidris canutus* 1.6%) (Williams and Simmons 2008b). According to Simmons and Brown (2009) 28 wetland bird species are of special concern in Namibia.

The coastal area between Swakopmund and Walvis Bay falls within a national IBA (Important Bird Area) – i.e. known as 30 km beach. Other IBA's in the area include the Walvis Bay and Sandwich Harbour (Global IBA, Marine Reserve and Namib-Naukluft Park – wetlands which are also classified as Ramsar sites [i.e. Namibia is signatory to the Ramsar Convention protecting important wetland sites] as well as globally Important Birding Area (IBA's) and the Mile 4 Salt works (north of Swakopmund – Global IBA, Private Nature Reserve) (Simmons 1998a). Coastal areas and wetlands are immensely important as 8 and 34 bird species are classified as critically endangered, endangered or vulnerable in each of the biomes (i.e. Coastal areas and Wetlands), respectively (Simmons 1998a).

Recently published summer bird counts from the Walvis Bay wetlands resulted in total counts of 118,850 birds (45 species) and 101,468 birds (41 species) of which 203 and 177 were Damara terns during 2013 and 2014, respectively (Bridgeford 2013, 2014). Other bird counts in the vicinity during the summer of 2013 resulted in 4,462 birds (22 species) – Mile 4 Salt Works – 255,633 birds (35 species) – Sandwich Harbour – 506 birds (30 species) – Swakop River mouth – 436 birds (9 species) – Swakopmund sewerage works – and 10,685 birds (25 species) at the Walvis Bay sewerage ponds (Kolberg 2013). Abovementioned counts indicate the importance of the general Swakopmund/Walvais Bay coastal areas for birds.

However, the most important bird known to occur (and breed) at the proposed Desert Rose development area is the Damara tern (*Sterna balaenarum*) classified as endemic and endangered under Namibian legislation and near threatened (population stable) by the IUCN (2014). With 98% of the Damara tern breeding population being in Namibia (Braby 2010a; Braby 2011; Crawford and Simmons 1997); very low inter-colony dispersal rates with only 70 known colonies (Braby 2011); the importance of the general Swakopmund/ Walvis Bay area cannot be stressed enough. Furthermore, the Caution Reef breeding colony (~13 to 120 nests since 1994) located at the proposed Desert Rose development area is viewed as the third largest known breeding colony (Braby 2011). Disturbance and urbanisation, especially off-road vehicles, impact on breeding success and consequently pose the biggest threat to Damara terns along the Namibian coast (Braby *et al.* 2001, Braby 2011, Braby and Braby 2002).

However, none of the important bird species – including Damara terns – are exclusively associated with the proposed Desert Rose development area.

Birds encountered during the fieldwork at the proposed Desert Rose Development area:

At least 78 species of birds were confirmed from the general area, either through direct observations (i.e. 16 species – 12 species included in Table 4 and another 4 Palaearctic migrant species) or as confirmed sightings using the author's previous records from the general area (i.e. 62 species – See Cunningham 2011a; Cunningham 2010a and

Cunningham 2010b). Of these species, 5 species are classified as endemic; 1 species as critically endangered, 3 species as endangered, 4 species as vulnerable and 2 species as specially protected by Namibian legislation (Simmons and Brown In press). Furthermore, the IUCN (2014) classifies 3 species as endangered, 5 species as near threatened and 2 species as vulnerable.

The 16 species actually encountered during the fieldwork are included in Table 5 (See Figures 10 to 12 for some examples of birds confirmed on site):

Table 5. Bird diversity confirmed at the proposed Desert Rose development area during the fieldwork conducted between 29 June and 2 July. Palaearctic migrants observed on site are also included.

Species: Scientific name	Species: Common name	Species Confirmed	Namibian conservation and legal status	International status	
				Southern Africa	IUCN
Pelecanus onocrotalus	Great White Pelican	√	E		
Phalacrocorax lucidus	White-breasted Cormorant	√			
Phalacrocorax capensis	Cape Cormorant	√		Breeding End	E
Egretta intermedia	Yellow-billed Egret	√			
Phoenicopterus ruber	Greater Flamingo	√	V		
Falco rupicolus	Rock Kestrel	√			
Charadrius marginatus	White-fronted Plover	√			
Numenius phaeopus	Common Whimbrel	√			
Pluvialis squatarola	Grey Plover	√			
Sterna sandvicensis	Sandwich Tern	√			
Arenaria interpres	Rudy Turnstone	√			
Larus dominicanus	Kelp Gull	√			
Larus hartlaubii	Hartlaub's Gull	√		End	
Sterna bergii	Swift Tern	√			
Columba livea	Rock Dove	√			
Corvus albus	Pied Crow	√			

Figure 10. Greater flamingo (*Phoenicopterus ruber*) and Cape cormorant (*Phalacrocorax capensis*) foraging and roosting along the coastal areas.

Figure 11. Sandwich tern (*Sterna sandvicensis*) were the most numerous tern observed in the area.

Figure 12. Kelp gull (*Larus dominicanus*) was the most commonly observed bird in the area.

The limited number of birds observed at the proposed Desert Rose development area during the fieldwork is due to the season (fewer birds – numbers and species – are present along the coast during the winter months); weather (fog and cold temperatures – e.g. temperature never above 16°C at midday) and short duration (3 days fieldwork only). Many more birds (and species) are known/expected to occur along this stretch of beach than presented in Tables 4 and 5 and the fieldwork can only be viewed as a snapshot in time and not on the importance of the area for birds.

Damara terns:
Damara tern (*Sterna balaenarum*) breed from southern Angola – first recorded during 2010 (Simmons 2010) – throughout suitable habitat in coastal Namibia and in a few parts of South Africa (Braby 2011). Very little is known about the breeding population in Angola while in South Africa their populations are small and declining. Crawford and Simmons (1997) estimate that 98% of the Damara terns breed in Namibia. Of the 70 known breeding colonies, 12 occur in South Africa and 1 in Angola while the rest are in Namibia (Braby 2011).

The largest colony (187-300 pairs) is at Hottentots Bay (north of Lűderitz) followed by Durissa Bay Pans (south of the Ugab River mouth), Caution Reef (at the proposed Desert Rose development area) and Meob Bay (south of Sandwich Harbour) (Braby 2011). The global population is estimated to range between 1001–2685 pairs, or 2002–5370 breeding individuals of which 87–93% (930–2347 pairs) occur in Namibia. Although most are known to breed in the Skeleton Coast Park (301–770 pairs), the heavily disturbed coastal areas of the Dorob National Park supports the second largest number between 237–571 pairs (Braby 2011).

The Caution Reef, Damara tern breeding area (Figure 13), has an estimated ~13 to 120 nests [60-110 minimum and maximum estimates] (long term studies conducted since 1994) and viewed as the third largest breeding colony in Namibia while the Dorob National Park has an estimated 237-571 breeding pairs (minimum and maximum estimates) (Braby 2011).

Breeding can occur as single attempts or in breeding colonies in a variety of suitable habitats – e.g. gravel plains, hard salt pans, stony areas, inter-dune flats – up to 8 km inland (typically 1-2 km) (Tarboton 2001).

Braby *et al.* (2001) showed that the active fencing off of the Caution Reef area increased the nest density by 25% and hatching success from 56 to 80% while Braby *et al.* (2009) showed similar results for another adjacent breeding colony – Horses Graveyard – with the number of chicks hatching increasing by 71% after fencing off that area.

Coastal developments have been known to result in the extinction of colonies in Namibia – e.g. 32 pairs used to breed at the now developed Dolphin Beach. Threats to breeding colonies are:

- Coastal developments;
- Off-road driving;
- Anthropogenic activities (e.g. increased predators due to increased litter);
- Diamond mining;
- Climate change (e.g. flooding of pans/bays); and
- Capture for sale (Angola).

No Damara terns were observed on site as very few birds are known to over winter along the Namibian coast with most migrating northwards to central and west Africa (Hockey *et al.* 2006) and peak breeding occurring between December and January (Tarboton 2001) (Figure 13).

Figure 13. A well vegetated section (i.e. rehabilitated since being protected) of the fenced off Damara tern breeding colony at Caution Reef.

3.5 Flora

3.5.1 Tree and Shrub Diversity

It is estimated that at least 20-39 species of larger trees and shrubs (>1m) Burke 2003 [24 sp.], Coats Palgrave 1983 [20 sp.], Craven and Marais (1986) [23 sp.], Curtis and Mannheimer 2005 [39 sp.], Mannheimer and Curtis 2009 [26 sp.], Van Wyk and Van Wyk 1997 [20 sp.]) occur in the general Swakopmund/ Walvis Bay, central coastal Namibia, area.

Southern Namib

According to Giess (1971) the Southern Namib stretches from the Swakop River southwards until Lüderitz. *Stipagrostis sabulicola* (tough dune grass) occurs with *Trianthema hereroeensis* on the dunes while the inter-dune flats (streets) are covered with *Stipagrostis gonatostachys* after rains. The eastern inland sections – pro-Namib – are dominated by *Stipagrostis obtusa* and *S. ciliata* after rains while the plains closer towards the coast are dominated by *Mesembryanthemum cryptanthum* (Giess 1971).

An interesting feature of the coastal areas is the extensive formation of gypsum crusts in the soil as a result of sulphur releases during upwelling events in the ocean in the past. These substrates support the most divers lichen fields in the world (Burke 2003). Namibia has some of the rarest and most interesting species of lichens in the world although many have still not been officially described (Craven and Marais 1986).

Table 6 indicates the larger tree and shrub diversity known and/or expected to occur in the general area between Swakopmund and Walvis Bay and are derived from Curtis and Mannheimer (2005) and Mannheimer and Curtis (2009). Some species indicated to possibly occur in the area according to Coats Palgrave (1983) and Van Wyk and Van Wyk (1997) is excluded here. Species indicated by Curtis and Mannheimer (2005) below are know from the quarter-degree square distribution principle used and don't necessarily occur along the coastal – Desert Rose – area. Trees and larger shrubs likely to occur in the general area indicated by Burke (2003) (trees, shrubs and stem succulents) and Craven and Marais (1986), are also included.

Table 6. Tree and shrub diversity (larger species) known and/or expected to occur in the general area – i.e. Swakopmund/Walvis Bay area – and/or author's previous records (√[1,2,3,4]) including this current study (√*).

Species: Scientific name	Expected: Curtis and Mannheimer (2005)	Expected: Mannheimer and Curtis (2009)	Expected: Burke (2003)	Expected: Craven and Marais (1986)	Species Confirmed	Namibian conservation and legal status
Acacia erioloba	√	√	√	√	√[1,3]	Protected (F)
Acacia reficiens	√	√		√	√[3]	
Acacia tortilis	√	√				
Acanthosicyos horridus	√	√	√	√	√[1,3]	Protected (F)
Adenia pechuelii	√					Endemic
Adenolobus garipensis	√	√	√		√[3]	
Adenolobus pechuelii			√	√		
Aloe asperifolia				√		
Aloe dichotoma	√					NC, C2
Aptosimum spinescens			√			
Arthraerua leubnitziae			√	√	√*, √[1,2,4]	Endemic

Asclepias buchenaviana				√		
Barleria lancifolia			√			
Boscia foetida	√		√		√[3]	
Cadaba aphylla	√					
Calicorema capitata			√			
Combretum imberbe	√	√				Protected (F)
Commiphora dinteri	√					Endemic
Commiphora glaucescens	√		√			
Commiphora oblanceolata	√					
Commiphora saxicola	√		√	√	√[3]	Endemic
Commiphora tenuipetiolata	√					
Commiphora virgata	√					Endemic
Commiphora wildii	√	√				
Cordia sinensis		√				
Cyphostemma currorii			√			
Dyerophytum africanum			√			
Euclea pseudebenus	√	√	√	√	√[3]	Protected (F)
Euphorbia damarana	√				√[3]	Endemic; C2
Euphorbia guerichiana	√					C2
Euphorbia virosa	√		√			C2
Faidherbia albida	√	√		√	√[1]	Protected (F)
Ficus cordata		√				Protected (F)
Ficus sycomorus	√	√				Protected (F)
Grewia tenax	√	√				
Gymnosporia senegalensis	√					
Hoodia currorii			√	√		
Hyphaene petersiana	√					
Ipomoea adenioides				√		
Lycium bosciifolium	√	√				
Lycium cinereum	√	√		√	√[3]	
Lycium hirsutum	√	√				
Lycium pumilum		√				
Lycium tetrandrum		√			√[1,4]	
Maerua juncea	√					
Maerua schinzii	√		√			Protected (F)
Monechma cleomoides			√			
Moringa ovalifolia			√			
Parkinsonia africana	√	√		√	√[3]	Protected (F)
Pechuel-Loeschea leubnitziae		√		√	√[1,3]	
Petalidium setosum			√	√		
Rhus marlothii	√					
Salsola sp. *S. arborea*, *S. aphylla*, *S. nollothensis*	√	√	√	√	√*, √[1,2,3,4]	
Salvadora persica	√	√	√	√		
Sarcocaulon marlothii				√		
Searsia marlothii		√				
Tamarix usneoides	√	√	√	√	√[1,3,4]	Protected (F)
Tetragonia reduplicata				√		
Welwitschia mirabilis	√	√	√	√	√[3]	NC, C2
Zygophyllum stapffii		√		√	√*, √[1,2,3,4]	

Endemic (Craven 1999)
F – Preservation of Trees and Forests Ordinance No. 37 of 1952 and/or Forest Act No. 72 of 1968 (Curtis and Mannheimer 2005, Mannheimer and Curtis 2009)
NC – Nature Conservation Ordinance No. 4 of 1975
C2 – CITES Appendix 2

√[1] – Cunningham (2011a); √[2] – Cunningham (2010a); √[3] – Cunningham (2010b); √[4] – Cunningham (2014); √* - This study

According to Curtis and Mannheimer (2005) and Mannheimer and Curtis (2009) between 26 and 39 species of larger trees and shrubs are known and/or expected to occur in the general Swakopmund/Walvis Bay area although not throughout the area, but rather associated with various habitats, mainly Kuiseb, Swakop and Tumas Rivers and rocky areas further inland. Scott and Scott (2008) identified 17 species of plants (including grasses) during a survey along the Swakop River, just north of the proposed Desert Rose development area.

Six species of trees and shrubs (15.4%) expected to occur in the Swakopmund/Walvis Bay area are classified as endemics, 10 species (25.6%) are protected under the Preservation of Trees and Forests Ordinance No. 37 of 1952 or Forest Act No. 72 of 1968, 2 species (5%) are protected under the Nature Conservation Ordinance No. 4 of 1975 while 5 species (13%) are classified as CITES Appendix II species. *Arthraerua leubnitziae* is endemic to the fog zone in the central Namib region (Burke 2003).

During the fieldwork, only 3 species – *Arthraerua leubnitziae* (Pencil bush – endemic), *Salsola nollothensis* (Salt bush/ganna) and *Zygophyllum stapffii* (Dollar bush) – of larger trees/shrubs were confirmed at the proposed Desert Rose development area (See Figures 1 and 6).

Table 7 indicates all flora species, but excluding grass (i.e. not limited to larger trees/shrubs only as in Table 6), observed at the proposed Desert Rose development area.

Table 7. Flora (excluding grass) observed at the proposed Desert Rose development area during this study (√*). All species included are the author's records from the general area although not necessarily the coastal section between Swakopmund and Walvis Bay during previous studies. Lichens are excluded here as the windblown sandy coastal area is not viewed as favoured habitat.

Species: Scientific name	Gravel Plains: North	Namibian conservation and legal status
Acacia erioloba		Protected (F)
Acanthosicyos horridus		Protected (F)
Arthraerua leubnitziae	√*	Endemic[1]
Brownanthus arenosus	√*	Near Endemic
Caparis hereoensis		
Citrullus lanatus		
Cyperus marginatus		
Faidherbia albida		Protected (F)
Felicia smaragdina		
Galenia africana		
Geigeria sp.		
Gossypium anomalum		
Heliotropium sp.		
Lycium tetrandrum		
Mesembryanthemum cryptanthum		
Mesembryanthemum guerichianum		
Myxopappus hereroensis		
Ornithogalum sp.		
Pechuel-Loeschea leubnitziae		
Salsola sp.	√*	
S. arborea, *S. aphylla*, *S. nollothensis*		
Sarcocornia perennis	√*	
Saueda sp.		

Senecio engleranus		
Sesuvium sesuvioides		
Tamarix usneoides		Protected (F)
Trianthema hereroensis		
Xanthodactylon turbinatum		
Zygophyllum clavatum	√*	
Zygophyllum simplex		
Zygophyllum stapffii	√*	

Endemic ([1]Craven 1999)
Near Endemic (Mannheimer *et al.* 2008)
F – Preservation of Trees and Forests Ordinance No. 37 of 1952 and/or Forest Act No. 72 of 1968 (Curtis and Mannheimer 2005, Mannheimer and Curtis 2009)

Only 6 species of flora were observed at the proposed Desert Rose development area with *Arthraerua leubnitziae*, *Brownanthus arenosus*, *Salsola nollothensis* and *Zygophyllum clavatum* – mainly growing as hummocks – being dominant throughout the area. *Arthraerua leubnitziae* is viewed as endemic although occurs widespread throughout much of the central coastal Namib (Burke 2003). *S. nollothensis* hummocks are more common in the southern portion of the development area while *A. leubnitziae*, *B. arenosus* and *Z. clavatum* more common in the northern and central portions (Figures 13 to 15).

Figure 13. *Salsola nollothensis* (Salt bush/ganna) hummocks more common in the southern portion of the development area.

Figure 14. Isolated hummocks of *Sarcocornia perennis* were observed in the northern portion, especially close to salt pan areas.

Figure 15. A few *Zygophyllum stapffii* (Dollar bush) individuals were observed on site.

Other species
Lichens
The overall diversity of lichens is poorly known from Namibia, especially the coastal areas and statistics on endemicity is even sparser (Craven 1998). To indicate how poorly known lichens are from Namibia, the recent publication by Schultz *et al.* (2009) indicating that 37 of the 39 lichen species collected during BIOTO surveys in the early/mid 2000's were new to science (i.e. new species), is a case in point. More than 120 species are expected to occur in the Namib Desert with the majority being uniquely related to the coastal fog belt (Wirth 2010). Lichen diversity is related to air humidity and generally decreases inland form the Namibian coast (Schults and Rambold 2007). Many lichens look similar are highly variable in appearance and notoriously difficult to identify unless with the use of a microscope (e.g. crustose lichens) or certain chemical tests. Off road driving is the biggest threat to these lichens which are often rare and unique to Namibia. Another importance of the lichens is that the endemic Damara Tern often uses these fields as a breeding ground (Craven and Marais 1986) including the northern gravel plains just south of the Swakop River east of the dune belt (Cunningham 2011a).

Lichen diversity and abundance decreases from the sandy/gravel plains just south of the Swakop River to the sandy/gypsum plains north of the Kuiseb River east of the dune belt. Cunningham (2010b, 2011) identified at least 7 to 10 species of lichens on the northern gravel plains east of the dune belt area just south of the Swakop River.

The closest lichen hotspots includes a Crustose lichen zone east of the dune belt area while extensive patches of Fruticose & Foliose lichens occur in the Mile 8 and Wlotzkasbaken areas between Swakopmund and Henties Bay – i.e. north of the proposed development area.

No lichens were observed during the rapid site assessment conducted at the proposed Desert Rose development area. This windblown sandy coastal area is also not viewed as favoured lichen habitat.

Aliens
No invasive alien species were observed at the proposed Desert Rose development area. Invasive alien species are known to occur in the Swakop and Kuiseb Rivers and species such as *Nicotiana glauca* (Wild Tobacco) and *Solanum nigrum* (Nightshade) have been observed east of the dune belt area (e.g. Cunningham 2014).

3.5.2 Grass Diversity

It is estimated that up to 48 grasses – 6 to 37 species – (Burke 2003 [6 sp.], Curtis and Marais 1986 [5 sp.], Müller 2007 [21 sp.], Müller 1984 [24 sp.], Van Oudshoorn 1999 [37 sp.]) occur in the general Swakopmund/Walvis Bay, central coastal, Namibia area.

Southern Namib
Desert grasses are dominated by the genus *Stipagrostis* (Lovegrove 1999). *Stipagrostis sabulicola* (tough dune grass) occurs with *Trianthema hereroeensis* on the dunes while the inter-dune flats (streets) are covered with *Stipagrostis gonatostachys* after rains. The eastern inland sections – pro-Namib – are dominated by *Stipagrostis obtusa* and *S. ciliata* after rains (Giess 1971, Lovegrove 1999). Possibly the most common and well adapted grass in the Swakopmund/ Walvis Bay area is the hardy salt loving *Odyssea paucinervis* (Müller 1984, Van Oudtshoorn 1999).

Table 8 indicates the grasses known and/or expected to occur in the general Swakopmund/Walvis Bay area and are derived from [1]Müller (1984), [2]Van Oudtshoorn (1999), [3]Burke (2003), [4]Curtis and Marais (1986) and [5]Müller (2007).

Table 8. Grass diversity known and/or expected to occur in the general area – i.e. Swakopmund/Walvis Bay area – and/or author's previous records (√[1,2,3]) including this study (√*).

Species: Scientific name	Species Confirmed	Namibian conservation and legal status	Ecological Status	Grazing Value
[2,5]*Anthephora pubescens*			Decreaser	High
[2]*Aristida adscensionis*			Increaser 2	Low
[2]*Aristida congesta*			Increaser 2	Low
[2,5]*Bachiaria deflexa*			Increaser 2	Average
[2,3]*Cenchrus ciliaris*			Decreaser	High
[1,2,3]*Centropodia glauca*			Decreaser	High
[1,2]*Chloris virgata*			Increaser 2	Average
[2,4]*Cladoraphis spinosa*	√[1]		Increaser 1	Average
[1,2,5]*Cynodon dactylon*	√[1]		Increaser 2	High

[1,2]*Dactyloctenium aegyptium*			Increaser 2	Average
[1,2]*Enneapogon cenchroides*			Increaser 2	Low
[1,2,3]*Enneapogon desvauxii*			Intermediate	Average
[1,2]*Enneapogon scaber*			?	Low
[2]*Enneapogon scoparius*			Increaser 2	Low
[1,5]*Entoplocamia aristulata*			Intermediate	Low
[1,5]*Eragrostis annulata*			Increaser 2	Low
[2]*Eragrostis cilianensis*			Increaser 2	Low
[1,2,5]*Eragrostis echinochloidea*			Increaser 2	Average
[2]*Eragrostis lehmanniana*			Increaser 2	Average
[2,3,5]*Eragrostis nindensis*			Increaser 2	Average
[1]*Eragrostis omahekensis*		Endemic	?	Low
[1,5]*Eragrostis porosa*			Intermediate	Low
[2]*Eragrostis rotifer*			Intermediate	Low
[2,5]*Eragrostis superba*			Increaser 2	Average
[2,5]*Fingerhuthia africana*			Decreaser	Average
[2]*Melinis repens*			Increaser 2	Low
[1,4,5]*Odyssea paucinervis*	√[1]		?	Low
[2,5]*Panicum repens*			Decreaser	High
[2,4]*Phragmites australis*	√[1,3]		Decreaser	Low
[1,5]*Pogonarthria fleckii*			Increaser 2	Low
[2]*Polypogon monspeliensis*			?	Average
[2]*Schmidtia kalahariensis*			Increaser 2	Low
[1,2]*Schmidtia pappophoroides*			Decreaser	High
[1]*Setaria appendiculata*			Decreaser	High
[2]*Setaria megaphylla*			Decreaser	High
[1,2]*Setaria verticillata*			Increaser 2	Average
[4]*Sporobolus consimilis*			?	Low
[2]*Sporobolus festivus*			Increaser 2	Low
[4]*Sporobolus nebulosus*			Increaser 2	Low
[1,2,3,5]*Stipagrostis ciliata*	√[2]		Decreaser	High
Stipagrostis hermanii	√*		?	?
[1,2,5]*Stipagrostis hirtigluma*	√[1]		Increaser 2	Low
[1,5]*Stipagrostis hochstetteriana*			Decreaser	Average
[1,2,5]*Stipagrostis namaquensis*			?	Average
[3]*Stipagrostis sabulicolia*	√[1]	Endemic*	?	?
[1,2,5]*Stipagrostis obtusa*	√[2]		Decreaser	High
[1,2,5]*Stipagrostis uniplumis*	√[1,2]		Increaser 2	Average
[1,2,5]*Tricholaena monachne*			Increaser 2	Average
[2,5]*Tragus berteronianus*			Increaser 2	Low

Endemic - Müller (1984); Endemic* - Burke (2003)
? – Undetermined in literature
√[1] – Cunningham (2011a); √[2] – Cunningham (2010b); √[3] – Cunningham (2014)

Between 21 and 24 species of grass potentially could occur in the Swakopmund/Walvis Bay area (Müller 1984, Müller 2007). According to Müller (1984) the endemic grass *Eragrostis omahekensis* potentially occurs in the general area although the updated Müller (2007) excludes this species suggesting that it probably does not occur in the area. Burke (2003) describes *Stipagrostis sabulicolia* as a “true Namib endemic” which only occurs in the dune fields of the Namib Desert.

Very few grasses were confirmed during various other recent studies in the area (See Cunningham 2010a, 2011 and 2014) as they are typically associated with rainfall events, which are infrequent in this coastal area.

Grasses are not an important component of the flora along the windblown sandy coastal, salt pan dominated, areas (Cunningham and Jankowitz 2010). The only grass identified during the rapid site assessment was remnants of the annual *Stipagrostis hermanii* on gravel plains.

4 IMPACT ASSESSMENT

All developments change or are destructive to the local fauna and flora to some or other degree. Assessing potential impacts is occasionally obvious, but more often difficult to predict accurately. Such predictions may change depending on the scope of the development – i.e. the development, once initiated, may have a different effect on the fauna and flora as originally predicted. Thus continued monitoring of such impacts during the development phase(s) is imperative.

Faunal loss/disturbance

Habitat loss associated with various developments would be localised and dependant on the activities – i.e. some activities may have more impact than others. The following table summarises the potential/envisaged impacts expected to occur (faunal loss/disturbance is closely linked to habitat loss):

Table 9. Faunal loss expected to occur with the proposed Desert Rose development between Swakopmund and Walvis Bay.

Description	Faunal loss/disturbance will vary depending on the scale/intensity of the development operation and associated and inevitable infrastructure. The impacts would be contained and/or limited depending on the various proposed developments envisaged. Each development would have to be assessed individually to ascertain the scale of impact.
Extent	Localised disruption/destruction of the habitat and thus consequently fauna associated directly with this habitat and the actual development sites. This however, would be limited to the development area with localised implications. Further developments – e.g. industry, road construction, etc. – throughout the general area would however increase the extent of impact.
Duration	The duration of the impact is expected to be permanent over most of the proposed development sites once established. Most fauna species (especially species associated with the vegetated dune hummocks – e.g. various reptiles and small mammals – and birds breeding in the area – e.g. Damara tern) are not expected to re-colonise the area after completion of the development(s) – i.e. duration viewed as permanent. Disturbances to larger mammals, not viewed as sedentary and/or permanently associated with the area, would not be affected as severely as these species are not permanently associated with the area – i.e. duration viewed as short to medium term. This however, would be limited to the development area with localised implications.

Intensity	The actual development site would be permanently altered with the intensity of faunal loss/disturbance depending on the species involved – e.g. slow moving and sedentary species will succumb to development while the more mobile species are expected to vacate the area. Implications are expected to be localised, depending on the scale of developments. The areas adjacent the development site should not be significantly affected. This, however, would depend on the proposed development, but should be limited to localised implications. Areas not directly affected by the development, although within the immediate vicinity, would be affected minimally. This would include dust, noise and other associated disturbances mainly associated with the construction phase(s). The effect that a variety of developments may have on the fauna is difficult to determine beforehand although increased disturbance associated with increased activities are expected. This would however be limited to the actual areas affected.
Mitigation	**The proposed Desert Rose development is expected to severely and permanently alter the current habitat.** **The most important fauna issue would be the Damara tern breeding colony at Caution Reef – currently fenced off for protection.** **The proposed development is expected to destroy the Caution Reef Damara tern breeding colony habitat. These birds are not expected to re-colonise the area – i.e. breed on envisaged open areas such as golf greens, open space, etc. – as they require specific habitat and little disturbance. It is unknown if the Caution Reef Damara tern population would breed elsewhere once disturbed, as these is no scientific evidence therefore at present.** **Main recommendations:** **1.** Avoid development and associated infrastructure in sensitive areas – e.g. Damara Tern breeding areas and vegetated dune hummocks (reptile habitat – e.g. *Bitis peringueyi* and *Meroles* sp. and small mammal habitat – e.g. dune hairy-footed gerbils). As the Caution Reef area is one of the largest (and best studied) Damara tern colonies, this development is expected to severely impact on the overall population dynamics of this species. **2.** Initiate a thorough survey of Damara tern breeding activity at the Caution Reef area. This data could be used to verify the latest breeding status at the colony and identify the most important part of the colony utilised by the terns. MET officials; ornithologists (scientists, including previous researchers) and resident birders should be used. **Alternative recommendations should development proceed:** **3.** Initiate an intensive Damara tern ringing programme prior to breeding (i.e. before the peak expected during December/January) at the Caution Reef colony. Attempt to capture (net) and ring as many birds as possible and include a specific Caution Reef colour coded ring combination for future visual identification. **4.** Initiate a long term study on Damara tern re-location and alternative breeding attempts/areas/success – using coded colour ring combination data. This would indicate if the birds breed elsewhere – e.g. Horses Graveyard, etc. – or not at all. Such scientific data could assist with future

	developments expected to occur in other Damara tern breeding colonies along the coast. **5.** Capture and relocate as many of the important reptiles – especially the endemic and unique *Bitis peringueyi* – and small mammals – e.g. dune hairy-footed gerbils – from the vegetated dune hummocks, as possible. **6.** Relocation should be to similar undisturbed habitats not expected to be developed along the coast – e.g. vegetated Kuiseb River mouth area south of Walvis Bay. **7.** Protect the most important part of the Damara tern breeding colony – i.e. area with highest density of nests – and incorporate this into the overall planning and design of the development (e.g. open space or conservation area, etc.). This area should be fully protected – fenced – and out of bounds for all activities. **General recommendations:** **8.** Implement and maintain track discipline limited to pre-determined tracks with maximum speed limits (e.g. 30km/h) as this would result in fewer faunal road mortalities and overall destruction of vegetated areas which serve as habitat to a variety of fauna. **9.** Avoid off road driving in areas prone to scarring (e.g. gypsum/gravel plains). Nocturnal driving should also be avoided as this result in the destruction of slow moving fauna – e.g. various reptiles and other nocturnal species. **10.** Avoid and/or limit the use of lights during nocturnal activities as this influence and/or affects various nocturnal species – e.g. especially migrating Palaearctic birds, bats, owls, etc. and contribute to “light pollution”. Use focused lighting for least effect. **11.** Prevent overnight activities during the construction phase(s). This could result in pollution; killing of perceived dangerous nocturnal species (e.g. snakes, etc.); illegal collection of species for the pet industry (e.g. chameleons), etc. **12.** Prevent and discourage any form of poaching, illegal collecting of veld foods (e.g. bird eggs, etc.), indiscriminate killing of perceived dangerous species (e.g. snakes, etc.), and the collection of wood (what little there is) as this would diminish and negatively affect the local fauna – especially during the construction phase(s). **13.** Initiate a suitable and appropriate refuse removal policy during the construction phase(s) as littering could result in certain animals becoming accustomed to humans and associated activity and result in typical problem animal scenarios – e.g. black-backed jackal, crows, gulls, etc. **14.** Include patches of well vegetated dune hummock areas into the overall landscaping (i.e. green/open spaces) during developments (including the development of access routes) as these serve as habitat for a myriad of fauna in an otherwise marginal area. **15.** Rehabilitation of the disturbed areas – i.e. initial development access route “scars” and associated tracks, as well as temporary accommodation sites. Preferably workers should be transported in/out to the construction sites on a daily basis to avoid excess damage to the local environment (e.g. pollution, poaching, etc.). Such rehabilitation would not only confirm the various construction companies’ environmental integrity, but also show true local commitment to the environment.

	16. Prevent (do not allow) domestic pets – e.g. cats and dogs – accompanying the workers during the construction phase as pets can cause considerable damage to the local fauna and would contribute to the plight of the Damara terns in the general area. The indiscriminate and wanton killing of the local fauna by such pets should be avoided at all cost. **17.** Educate/inform contractors and staff on dangerous and protected species to avoid and the consequences of illegal collection of such species. Liaise with MET to provide this service as the area falls within the Dorob National Park **18.** Investigate the idea of employing a qualified environmental officer (EO) during the construction phase to ensure the appropriate management of the wildlife and ecological processes. This would ensure proper management.
Frequency of occurrence	Expected to be "once off" and only affecting the selected site(s).
Probability	Definite (100%) negative impact on fauna – especially the important Damara tern breeding colony at Caution Reef – is expected in the various development areas as well as the access route construction sites including the future (i.e. planned) developments. Highly Probable (75%) negative impact on fauna is expected in the general areas as a result of noise, increased activities, etc. Probable (50%) negative impact on fauna is expected from the infrastructure (roads/tracks). Precautionary principle (e.g. avoid unique habitat features as well as adhering to the proposed mitigating measures would minimise this) would decrease the significance of these potential impacts.
Significance	Before mitigation: **High** After mitigation: **Medium** to **Low**
Status of the impact	Negative Localised unique habitats (e.g. Damara tern breeding habitats, vegetated dune hummocks, etc.) with associated fauna would bear the brunt of this proposed development, but be limited in extent and only permanent at the actual development sites and access routes.
Legal requirements	Fauna related: Nature Conservation Ordinance No. 4 of 1975, CITES, IUCN and SARDB Habitat – Flora related: Preservation of Trees and Forests Ordinance No. 37 of 1952, Forest Act No. 72 of 1968, Nature Conservation Ordinance No. 4 of 1975, CITES
Degree of confidence in predictions	As an ecologist I am sure of the above-mentioned predictions made and would suggest that the mitigation measures be implemented to minimise potentially negative aspects regarding the local fauna in the area.

Floral loss/disturbance

Habitat loss associated with various developments (including tourism) would be localised and dependant on the activities – i.e. some activities may have more impact than others. The following table summarises the potential/envisaged impacts expected to occur (floral loss/disturbance is closely linked to habitat loss):

Table 10. Floral loss expected to occur with the proposed Desert Rose developments between Swakopmund and Walvis Bay.

Description	Floral loss/disturbance will vary depending on the scale/intensity of the development operation and associated and inevitable infrastructure. The impacts would be contained and/or limited depending on the various proposed developments envisaged. Each development would have to be assessed individually to ascertain the scale of impact.
Extent	Localised disruption/destruction of the habitat and thus consequently flora associated directly with this habitat and the actual development sites. This however, would be limited to the development area with localised implications. Further developments – e.g. industry, road construction, etc. – throughout the area would however increase the extent of impact.
Duration	The duration of the impact is expected to be permanent over most of the proposed development sites once established. Most species, especially annuals, are expected to re-colonise open areas after completion of the development(s) – i.e. duration viewed as short to medium term. This however, would be limited to the development area with localised implications.
Intensity	The actual development sites would be permanently altered with the intensity of floral loss depending on the species involved – e.g. slow growing species will be affected most. Implications are expected to be localised, depending on the scale of developments. The areas adjacent the development sites should not be significantly affected. This, however, would depend on the proposed development, but should be limited to localised implications. Areas not directly affected by the development, although within the immediate vicinity, would be affected minimally. The effect that a variety of developments may have on the flora is difficult to determine beforehand as this is dependent on the type of developments. This would however be limited to the actual areas affected.
Mitigation	**1.** Avoid development and associated infrastructure in sensitive areas – e.g. vegetated dune hummocks. This would minimise the negative effect on the local environment especially unique features serving as habitat to various species. **2.** Identify protected and unique species associated with the vegetated dune hummocks before the commencement of development activities in areas where these occur and avoid. **3.** Prevent and discourage the collecting of firewood (what little there is) as dead wood has an important ecological role – e.g. nutrient cycling; soil

	fertility; habitat to vertebrates and invertebrates, etc. **4.** Prevent the planting of potentially alien invasive plant species (e.g. *Pennisetum setaceum*, etc.) for ornamental purposes as part of the landscaping at the various developments, should these be approved – e.g. golf course, green/open areas, etc. Alien species often "escape" and become invasive causing further ecological damage. **5.** Incorporate the natural vegetation – especially vegetated dune hummocks – into the overall landscaping. This would require less maintenance (e.g. water) than alternative vegetation as well as support the natural ambiance of the area. **6.** Rehabilitation of the disturbed areas – i.e. initial development access route "scars" and associated tracks, as well as temporary accommodation sites. Preferably workers should be transported in/out to the construction sites on a daily basis to avoid excess damage to the local environment (e.g. wood and plant collection, etc.). Such rehabilitation would not only confirm the various development companies' environmental integrity, but also show true local commitment to the environment. **7.** Educate/inform contractors and staff of the importance of coastal vegetation, especially vegetated dune hummocks and the consequences of damaging these areas as well as the illegal collection of wood. Liaise with MET to provide this service as the area falls within the Dorob National Park **8.** Investigate the idea of employing a qualified environmental officer (EO) during the construction phase to ensure the appropriate management of the flora and ecological processes. This would ensure proper management.
Frequency of occurrence	Expected to be a "once off" issue affecting the selected site(s).
Probability	Definite (100%) negative impact on flora is expected in the actual development areas as well as the access route construction sites. This however, would be much localised and cover limited areas. Highly Probable (75%) negative impact on flora is expected from the infrastructure (roads/tracks). Precautionary principle (e.g. avoid unique habitat features as well as adhering to the proposed mitigating measures would minimise this) would decrease the significance of these potential impacts.
Significance	Before mitigation: **High** After mitigation: **Medium** to **Low**
Status of the impact	Negative Localised unique habitats (e.g. vegetated dune hummocks, etc.) with associated flora would bear the brunt of this proposed development, but be limited in extent and only permanent at the actual development sites and access routes.
Legal requirements	Flora related: Preservation of Trees and Forests Ordinance No. 37 of 1952, Forest Act No. 72 of 1968, Nature Conservation Ordinance No. 4 of 1975, CITES

Degree of confidence in predictions	As an ecologist I am sure of the above mentioned predictions made and would suggest that the mitigation measures be implemented to minimise potentially negative aspects regarding the local flora in the area.

5 CONCLUSION

Vertebrate fauna
It is estimated that at least 54 reptile, 7 amphibian, 43 mammal and 182 bird species (breeding residents) are known to or expected to occur in the general area of which a large proportion are endemics. Endemics include at least 50% of the reptiles, 43% of the amphibians, 26% of the mammals and 5% (7 of the 14 Namibian endemics) of all the breeding and/or resident birds known and/or expected to occur in the general area.

Development and recreation (e.g. "dune bashing" and quad bikes) are possibly the biggest threats to vertebrate fauna, especially reptiles and ground nesting birds, in the area between Swakopmund and Walvis Bay. Species most likely to be adversely affected by developments would be the avian fauna specifically associated with these areas. The Damara Tern and the active/known breeding colony at Caution Reef are viewed as the most important species and area to be negatively affected by the proposed Desert Rose developments.

As all development have potential negative environmental consequences, identifying the most important faunal species including high risk habitats beforehand, coupled with environmentally acceptable mitigating factors, lessens the overall impact of such development.

Reptiles
The high percentage of endemic reptile species (50%) known and/or expected to occur in the general area underscores the importance of this area for reptiles. Reptile species of concern are the 2 thread snakes (*Leptotyphlops occidentalis* and *L. labialis*) as well as the sand burrowing/dwelling species such as *Bitis peringueyi* and the various *Meroles* species, especially *Meroles micropholidotus* classified as endemic and rare, as well as the high proportion (81%) of endemic gecko (e.g. *Pachydactylus* species) species of which very little is known about their ecological role and actual status in Namibia. The seemingly barren sandy dune and gravel plain areas are host to a variety of reptile fauna not often expected and/or acknowledged. Poorly planned and executed development and recreation activities could affect these species negatively.

However, none of the important reptile species are exclusively associated with the proposed Desert Rose development area.

Amphibians
Amphibians are generally not viewed as extremely important in saline coastal areas which are marginal habitat for most amphibians. Although 43% of the amphibians expected to occur in the general area are endemic to Namibia they are expected to occur further inland – i.e. the Kuiseb and Swakop Rivers and rocky outcrops with temporary pools associated with these landforms, etc. – and not directly associated with the proposed development area between Swakopmund and Walvis Bay which is viewed as marginal amphibian habitat at best. The endemic *Phrynomantis annectens* is probably the amphibian of greatest concern in the area although it occurs widespread throughout large parts of Namibia.

However, none of the important amphibian species are exclusively associated with the proposed Desert Rose development area.

Mammals
Endemic mammals expected to occur in the general area make up a relatively large percentage (25.6%) of the mammals known and/or expected from the area. Endemic mammal species of concern include the mole *Eremitalpa granti* and the two bats *Laephotis namibensis* and *Cistugo seabrai* as well as the Hairy-footed Gerbils (*Gerbillurus* sp.). Both bats are very poorly known with only a few records from the general area making them particularly important. The predator of concern is the brown hyena (*Hyaena brunnea*) which is classified locally as insufficiently known, probably vulnerable; with an international status of near threatened (SARDB 2004, IUCN 2014). The area is not viewed as suitable as permanent habitat and brown hyena are not expected to be resident in the area.

However, none of the important mammal species are exclusively associated with the proposed Desert Rose development area.

Birds
The high proportion of endemic birds of which 50% (7 of 14 species) are endemic to Namibia and which are known and/or expected to occur in the general area is important and should be taken into consideration regarding development and various activities in the area. Species of greatest concern include all the endemics (e.g. Dune and Gray's Larks – although these species are more common east of the dune belt) as well as the gravel plain breeding Damara tern (*Sterna balaenarum* – near threatened) (IUCN 2014).

Damara tern is most threatened by development in the proposed Desert Rose development area. With 98% of the Damara tern breeding population being in Namibia (Braby 2010a,b; Braby *et al.* 2009, Braby 2011; Crawford and Simmons 1997); very low inter-colony dispersal rates with only 70 known colonies (Braby 2011), the importance of the general area, especially the Caution Reef breeding colony, cannot be stressed enough. The Caution Reef breeding colony is also viewed as one of the most important breeding sites for this species. As the global population for Damara terns is estimated at between 1001 to 2685 breeding pairs (Braby 2011) the estimated 60 to 110 breeding pairs (minimum and maximum) for the Caution Reef area makes up between 25% and 46% of the breeding population in the Dorob National Park (on minimum numbers – i.e. 237 pairs) and 6% and 11% of the entire population (on minimum numbers – i.e. 1001 pairs). The Caution Reef colony thus contributes significantly to the entire Damara tern breeding population. Although stated as "population stable" by the IUCN (2014) any significant disturbance, especially related to breeding success, could put the entire population in a decline. Disturbance and urbanisation, especially urban development and off-road vehicles, impact on breeding success and consequently pose the biggest threat to Damara terns along the Namibian coast (Braby *et al.* 2001, Braby *et al.* 2009, Braby 2011, Braby and Braby 2002). Development – i.e. destruction – of this Damara tern breeding colony will undoubtedly negatively affect the population dynamics of this species although to what extent is currently unknown.

Furthermore, the Namibian coast is extremely important for various bird species including Palaearctic migrants (mainly during summer), with the Caution Reef coastal area also viewed as an IBA (Important Birding Area) – i.e. important feeding, resting and roosting spot for a variety of other important marine birds (e.g. Cape cormorant, greater flamingo, great white pelican, etc.).

Flora
Between 26 and 39 species of larger trees and shrubs are known and/or expected to occur in the general area of which 6 species are classified as endemic (i.e. 15.4%) while up to 48 grasses – 6 to 37 species – occur in the general area.

During the fieldwork, only 6 species of shrubs (1 species endemic although occurs widespread throughout the central Namib) and 1 species of grass were confirmed from the general area.

Often deserts and plants associated with this marginal area look “dead” although are not, and thus not viewed as important. All desert vegetation serves as a source of habitat for desert dwelling fauna – e.g. arthropods and reptiles.

The most important feature are the well vegetated dune hummocks – especially within parts of the fenced off Caution Reef Damara tern breeding colony – which serve as habitat for a variety of vertebrate fauna.

However, none of the flora species are exclusively associated with the proposed Desert Rose development area.

Sensitive areas

The overall area is formally protected within the recently proclaimed Dorob National Park. According to the Uranium Rush Strategic Environmental Assessment (See MME 2010) conducted for the entire central coastal area, the following sensitive areas were identified in the immediate Desert Rose development area:

Biodiversity red flag areas:
Immediate area:

- Coastal strip between the beach and coastal road (Coastal bird (some near threatened and threatened species, including Damara tern breeding areas), dune hummocks with endemic coastal invertebrates and reptiles, brown hyena, lichens and marine life, surf zone species)

General area:

- Coastal area immediately north of Walvis Bay (e.g. Important bird areas; high density of waders along beach; Damara Tern breeding areas);
- Swakopmund surrounds (Important Bird Areas at Panther Baken (salt works) and Swakop River Mouth);
- Walvis Bay Lagoon (e.g. internationally recognised RAMSAR wetland and Important Birding Area).

Biodiversity yellow flag area:
General area:

- Inland Gravel Plains (e.g. Lichens, invertebrates and biodiversity associated with Tumas drainage area. Tumas ‘mouth’ – reedbed and ephemeral spring on eastern edge of dunes, hummocks and ephemeral wetland) – i.e. east of the dune belt.

The proposed Desert Rose development area thus fall within the biodiversity red flag area (See above) with Damara tern breeding grounds, vegetated dune hummocks, endemic coastal invertebrates and reptiles, brown hyena, lichens and marine life and surf zone species, viewed as the most important (MME 2010).

The areas of most concern from a vertebrate fauna and flora perspective – ranked in importance from **a – c** are expected to be:

a) Damara tern breeding grounds – i.e. Caution Reef colony

The global and regional importance of the Damara tern – especially the importance (3rd largest breeding colony in Namibia) of the Caution Reef breeding colony – is viewed as the most important feature in the Desert Rose development area.

Destruction of this site could directly impact on the global population dynamics of the Damara terns although to what extent is currently not clear. It is unknown if the birds favouring the Caution Reef breeding site would disperse to other areas if development proceeds, and although expected, has not yet been verified scientifically.

Development in this area should be limited and/or avoided if the Damara terns are to be protected.

b) Vegetated dune hummocks

The vegetated dune hummocks serve as habitat to a variety of vertebrate fauna (Seely 2010) and although not unique to the proposed Desert Rose development area is nevertheless important habitat.

Development in this area should be limited and/or avoided if the coastal dune hummocks are to be protected. These dune hummocks are however not unique to the specific site.

c) Sandy beach area

The importance of the sandy beach areas are for foraging/resting/roosting marine birds, especially Palaearctic species, although not unique to the proposed Desert Rose development area is nevertheless still viewed as important habitat. The area is also viewed as an Important Birding Area (IBA) of national importance.

Development in this area should be limited and/or avoided if marine birds, especially Palaearctic migrants, are to be favoured. The area, albeit important, is not unique to the proposed Desert Rose development area.

Another important habitat is the rocky shores, but not discussed here further as it does not fall within the scope of this study.

6 REFERENCES

Alexander, G. and Marais, J. 2007. A guide to the reptiles of southern Africa. Struik Publishers, Cape Town, RSA.

Barnard, P. 1998. Underprotected habitats. In: Barnard, P. (ed.). Biological diversity in Namibia: a country study. Windhoek: Namibian National Biodiversity Task Force.

Bethune, S., Shaw, D. and Roberts, K.S. 2007. Wetlands of Namibia. John Meinert Printing, Windhoek.

Branch, B. 1998. Field guide to snakes and other reptiles of southern Africa. Struik Publishers, Cape Town, RSA.

Branch, B. 2008. Tortoises, terrapins and turtles of Africa. Struik Publishers, Cape Town, RSA.

Boycott, R.C. and Bourquin, O. 2000. The Southern African Tortoise Book. O Bourquin, Hilton, RSA.

Braby, J. 2010a. New migration records for the Damara Tern *Sterna balaenerum*. *Ornithological Observations* 1: 38-41.

Braby, J. 2010b. The Damara Tern: What we know and what we don’t. Unpublished Report, NACOMA, Swakopmund, Namibia.

Braby, J, 2011. The Biology and conservation of the Damara Tern in Namibia. PhD thesis, University of Cape Town, RSA.

Braby, R., Shapira, A. and Simmons, R.E. 2001. Successful conservation measures and new breeding records for Damara terns *Sterna balaenarum* in Namibia. *Marine Ornithology* 29(2): 81-84.

Braby, J. and Braby, N. 2002. Report on daily observations at the breeding colony of Damara terns *Sterna balaenarum* south of Swakopmund in the gravel plains surrounding the horses' grave yards during the 2001/2 season. Unpublished report, MET, Swakopmund.

Braby, J., Braby, R.J., Braby, N. and Simmons, R.E. 2009. Protecting Damara Terns *Sterna balaenarum* from recreational disturbance in the Namib Desert increases breeding density and overall success. *Ostrich* 80(2): 71-75.

Bridgeford, P. 2013. African waterbird census – Walvis Bay Ramsar site, 9/10 February 2013. Unpublished report, Walvis Bay.

Bridgeford, P. 2014. African waterbird census – Walvis Bay Ramsar site, 15/16 February 2014. Unpublished report, Walvis Bay.

Broadley, D.G. 1983. Fitzsimons' Snakes of southern Africa. Jonathan Ball and AD. Donker Publishers, Parklands, RSA.

Burke, A. 2003. Wild flowers of the Central Namib. Namibia Scientific Society, Windhoek.

Buys, P.J. and Buys, P.J.C. 1983. Snakes of Namibia. Gamsberg Macmillan Publishers, Windhoek, Namibia.

Carruthers, V.C. 2001. Frogs and frogging in southern Africa. Struik Publishers, Cape Town, RSA.

Channing, A. 2001. Amphibians of Central and Southern Africa. Protea Bookhouse, Pretoria, RSA.

Channing, A. and Griffin, M. 1993. An annotated checklist of the frogs of Namibia. *Madoqua* 18(2): 101-116.

Coats Palgrave, K. 1983. Trees of Southern Africa. Struik Publishers, Cape Town, RSA.

Craven, P. 1998. Lichen diversity in Namibia. In: Barnard, P. (ed.). Biological diversity in Namibia: a country study. Windhoek: Namibian National Biodiversity Task Force.

Craven, P. (ed.). 1999. A checklist of Namibian plant species. Southern African Botanical Diversity Network Report No. 7, SABONET, Windhoek.

Craven, P. and Marais, C. 1986. Namib Flora. Gamsberg Macmillan Publishers, Windhoek.

Crawford, R.J.M. and Simmons, R.E. 1997. Damara Tern *Sterna baleanarum*. In: Harrison, J., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Brown, C.J. (Eds). The atlas of southern African birds. Vol 1: Non-passerines. Johannesburg: BirdLife South Africa pp 480–481.

Cunningham, P.L. 2006. A Guide to the Tortoises of Namibia. Polytechnic of Namibia, Windhoek.

Cunningham, P.L. 2010a. Vertebrate fauna and flora observed at Farm 37, Walvis Bay, Wind Energy Facility. Unpublished Report, Risk Based Solutions, Windhoek.

Cunningham, P.L. 2010b. Vertebrate fauna and flora associated with the uranium EPL 3496 – Inca & TRS areas. Unpublished Report, Softchem, Johannesburg.

Cunningham, P.L. 2011a. Biophysical assessment (Vertebrate fauna & Flora) associated with the Kuiseb Delta and Dune Belt area. Unpublished report, University Central Consultancy Bureau; University of Namibia; Windhoek.

Cunningham, P.L. 2011b. Biodiversity Impact Assessment related to the movement of fauna – Swakop South Pipeline. Unpublished report, EnviroDynamics, Windhoek.

Cunningham, P.L. 2014. Biophysical assessment (Vertebrate fauna & Flora): Swartzenkuppe-Swakopmund pipeline infrastructure developments. Unpublished report, Aurecon, Windhoek.

Cunningham, P.L. and Jankowitz, W. 2010. A review of fauna and flora associated with coastal and inland saline flats from Namibia with special reference to the Etosha Pan. *Sabkha Ecosystems Volume III: Africa and Southern Europe. DOI: 10.1007/978-90-481-9673-9_2.* Springer Science & Business Media.

Curtis, B. and Barnard, P. 1998. Sites and species of biological, economic or archaeological importance. In: Barnard, P. (ed.). Biological diversity in Namibia: a country study. Windhoek: Namibian National Biodiversity Task Force.

Curtis, B. and Mannheimer, C. 2005. Tree Atlas of Namibia. National Botanical Research Institute, Windhoek, Namibia.

De Graaff, G. 1981. The rodents of southern Africa. Buterworths, RSA.

Du Preez, L. and Carruthers, V. 2009. A complete guide to the frogs of southern Africa. Struik Publishers, Cape Town, RSA.

Estes, R.D. 1995. The behaviour guide to African mammals. Russel Friedman Books, Halfway House, RSA.

Giess, W. 1971. A preliminary vegetation map of South West Africa. *Dinteria* 4: 1 – 114.

Griffin, M. 1998a. Reptile diversity. In: Barnard, P. (ed.). Biological diversity in Namibia: a country study. Windhoek: Namibian National Biodiversity Task Force.

Griffin, M. 1998b. Amphibian diversity. In: Barnard, P. (ed.). Biological diversity in Namibia: a country study. Windhoek: Namibian National Biodiversity Task Force.

Griffin, M. 1998c. Mammal diversity. In: Barnard, P. (ed.). Biological diversity in Namibia: a country study. Windhoek: Namibian National Biodiversity Task Force.

Griffin, M. 2003. Annotated checklist and provisional national conservation status of Namibian reptiles. Ministry of Environment and Tourism, Windhoek.

Griffin, M. and Coetzee, C.G. 2005. Annotated checklist and provisional national conservation status of Namibian mammals. Ministry of Environment and Tourism, Windhoek.

Hebbard, S. n.d. A close-up view of the Namib and some of its fascinating reptiles. ST Promotions,Swakopmund, Namibia.

Hockey, P.A.R., Dean, W.R.J. and Ryan, P.G. 2006. Roberts Birds of Southern Africa VII Edition. John Voelcker Bird Book Fund.

IUCN, 2014. IUCN Red List of Threatened Species. IUCN, Gland, Switzerland.

Jacobson, P.J., Jacobson, K.M., and Seely, M.K. 1995. Ephemeral rivers and their catchments: sustaining people and development in western Namibia. Desert Research Foundation of Namibia, Windhoek.

Joubert, E. and Mostert, P.M.K. 1975. Distribution patterns and status of some mammals in South West Africa. *Madoqua* 9(1): 5-44.

Kolberg, H. 2013. Summary of the 2013 summer wetland bird counts in Namibia. Unpublished report, Ministry of Environment and Tourism, Windhoek.

Kolberg, H. n.d. Preliminary Inventory of Namibia's Wetlands. Directorate Scientific Services, Ministry of Environment and Tourism, Windhoek, Namibia.

Komen, L. n.d. The Owls of Namibia – Identification and General Information. NARREC, Windhoek.

Lovegrove, B. 1999. The living deserts of southern Africa. Fernwood Press, Vlaeberg, RSA.

Maclean, G.L. 1985. Robert's birds of southern Africa. John Voelcker Bird Book Fund.

Maggs, G. 1998. Plant diversity in Namibia. In: Barnard, P. (ed.). Biological diversity in Namibia: a country study. Windhoek: Namibian National Biodiversity Task Force.

Mannheimer, C. and Curtis, B. 2009. Le Roux and Müller's field guide to the trees and shrubs of Namibia. Macmillan Education, Windhoek.

Marais, J. 1992. A complete guide to the snakes of southern Africa. Southern Book Publishers, Witwatersrand University Press, Johannesburg, RSA.

Mendelsohn, J., Jarvis, A., Roberts, C. and Robertson, T. 2004. Atlas of Namibia – a portrait of the land and its people. David Philip Publishers, Cape Town.

MME, 2010. Strategic Environmental Assessment for the central Namib Uranium Rush. Ministry of Mines and Energy, Windhoek, Republic of Namibia.

Monadjem, A., Taylor, P.J., F.P.D. Cotterill and M.C. Schoeman. 2010. Bats of southern and central Africa. Wits University press, Johannesburg, RSA.

Müller, M.A.N. 1984. Grasses of South West Africa/Namibia. John Meinert Publishers (Pty) Ltd, Windhoek, Namibia.

Müller, M.A.N. 2007. Grasses of Namibia. John Meinert Publishers (Pty) Ltd, Windhoek, Namibia.

NACSO, 2010. Namibia's communal conservancies: a review of progress and challenges in 2009. NACSO, Windhoek.

Passmore, N.I. and Carruthers, V.C. 1995. South African Frogs - A complete guide. Southern Book Publishers, Witwatersrand University Press, Johannesburg, RSA.

SARDB, 2004. CBSG Southern Africa. In: Griffin, M. 2005. Annotated checklist and provisional national conservation status of Namibian mammals. Ministry of Environment and Tourism, Windhoek.

Seely, M. 2010. The Namib. Natural history of an ancient desert. DRFN, Windhoek.

Schultz, M. and Rambold, G. 2007. Diversity shifts and ecology of soil lichens in central Namibia. Talk, Ecological Society of Germany, Austria and Switzerland (GfÖ), 37th Annual Meeting, Marburg: 12/9/2007 to 15/9/2007.

Schultz, M., Zedda, L. and Rambold, G. 2009. New records of lichen taxa from Namibia and South Africa. *Bibliotheca Lichenologica* 99: 315-354.

Shaw, D., Bethune, S. and Roberts, K. 2004. Wetlands of Namibia. Solitaire Press, Windhoek.

Simmons, R.E. 1998a. Important Bird Areas (IBA's) in Namibia. In: Barnard, P. (ed.). Biological diversity in Namibia: a country study. Windhoek: Namibian National Biodiversity Task Force.

Simmons, R.E. 1998b. Areas of high species endemism. In: Barnard, P. (ed.). Biological diversity in Namibia: a country study. Windhoek: Namibian National Biodiversity Task Force.

Simmons, R.E. 2010. First breeding records for Damara Terns and density of other shorebirds along Angola's Namib Desert coast. *Ostrich* 81:19–23.

Simmons, R.E. and Brown, C.J. In press. Birds to watch in Namibia: red, rare and endemic species. National Biodiversity Programme, Windhoek.

Skinner, J.D. and Smithers, R.H.N. 1990. The mammals of the southern African subregion. University of Pretoria, RSA.

Skinner, J.D. and Chimimba, C.T. 2005. The mammals of the southern African subregion. Cambridge University Press, Cape Town, RSA.

Tarboton, W. 2001. A guide to the nests and eggs of southern African birds. Struik Publishers, Cape Town, RSA.

Taylor, P.J. 2000. Bats of southern Africa. University of Natal Press, RSA.

Tolley, K. and Burger, M. 2007. Chameleons of southern Africa. Struik Nature, Cape Town, RSA.

Van der Merwe, J.H. 1983. National Atlas of South West Africa (Namibia). National Book Printers, Cape Town, South Africa.

Van Oudtshoorn, F. 1999. Guide to grasses of southern Africa. Briza Publications, Pretoria, South Africa.

Van Wyk, B. and Van Wyk, P. 1997. Field guide to trees of Southern Africa. Cape Town: Struik Publishers.

Whitelaw, D.A., Underhill, L.G., Cooper, J. and Clining, C.F. 1978. Waders (Charadrii) and other birds on the Namib Coast: counts and conservation priorities. *Madoqua* 2(2): 137-150.

Williams, A.J. and Simmons, R.E. 2008a. The importance of wetlands along Namibia's desert coast for African waterbirds. Proceedings of the Namib Coastal Marine Bird Action Plan, 1 April 2008, Swakopmund.

Williams, A.J. and Simmons, R.E. 2008b. Africa's Namib desert coast supports >200 000 Holacrtic shorebirds. Proceedings of the Namib Coastal Marine Bird Action Plan, 1 April 2008, Swakopmund.

Wirth, V. 2010. Lichens of the Namib Desert. Klaus Hess Verlag, Göttingen-Windhoek.

17.2.

THE BIOLOGY AND CONSERVATION OF THE DAMARA TERN IN NAMIBIA – THESIS BY JUSTINE BRABY

The Biology and Conservation of the Damara Tern in Namibia

by Justine Braby

Thesis presented for the Degree of

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For my parents,

Rod and Sigi Braby,

who have devoted so much to the Damara Tern

Table of Contents

Abstract

Author: Justine Braby

Title: The Biology and Conservation of the Damara Tern in Namibia

Date: February 2011

The globally Near-threatened Damara Tern *Sterna balaenarum* is little known and faces several conservation issues. The aim of this study was to provide a description of the ecology and numbers of the species and discuss conservation management plans that will effectively ensure its survival. Because 98% of the population breeds in Namibia, all data for the study pertaining to the species' breeding biology were collected here.

Overall breeding success (probability of fledging one chick per pair per season) in Namibia was 0.36, although breeding success fluctuated between seasons and colonies. Predation of eggs and chicks was found to be the main factor impacting the breeding success of Damara Terns. Chick growth rate was slower than that of chicks of similar species. Resources allocated to growth favoured initial development of legs, then wings, and lastly, bill.

Immature survival from fledging to breeding was estimated using mark-capture-recapture techniques and found to be 0.59 (95% confidence interval=0.48–0.68). This estimate includes an element of chick mortality. The survival estimate for chicks older than 23 days (fledging age) was 0.84. Age at first breeding was found to be three to four years. Annual adult survival was found to be 0.88 (95% CI=0.73–0.96). Annual dispersal between two adjacent breeding colonies was 0.06 (95% CI=0.03–0.12); these low

dispersal probabilities indicate that protection of breeding sites is an important management approach for the species.

Prey capture success of Damara Terns in relation to six environmental variables was investigated at two colonies in southern Namibia. Prey capture success was greatest at high tide, strong winds and in least turbid water. Overall prey capture success was 30.5%. (SD=3.1%).

Mining activities, in the form of discharging sediment into the sea where breeding Damara Terns fed, were not found to overall significantly impact the breeding success of Damara Terns at one colony in southern Namibia. The effectiveness of conservation measures on breeding Damara Terns was assessed at a colony vulnerable to extensive recreational off-road vehicle disturbances in central Namibia. The study found that Damara Terns benefited from reduced disturbance because the access restrictions prevented entry to the colony by off-road vehicles.

A review of all accessible information of breeding populations in Angola, Namibia and South Africa found that 70 breeding colonies exist globally. The breeding population of Damara Terns was estimated to range up to 5370 breeding individuals. The continued survival of the species requires an urgent updated survey of the breeding population to reassess the species' conservation status. Conservation measures should focus on the protection of important breeding colony sites in Namibia, and also at the extremities of the range in South Africa and Angola. On migration along the west coast of Africa, and during the non-breeding season in West Africa, legal and enforced protection of Damara Terns from human disturbance (such as off-road driving trampling nests, trapping and killing birds, indirect disturbances affecting breeding and feeding habitat) is required.

Layout and contributions

This thesis consists of eight main chapters, most of which are written as papers for submission to a journal. Tables and figures follow the text of each chapter; references for all chapters are combined at the end of the thesis.

I collected all field data in southern Namibia from January 2007 to March 2009, and at various colonies in central Namibia from December 2009 to February 2010, and have contributed to field data collection at most other Damara Tern colonies since 1995. I collated, computerized and validated monitoring data for Damara Terns collected by staff of the Ministry of Environment and Tourism for various breeding areas from 1982–1993 and by Rod and Sigi Braby who monitored the breeding sites called Caution Reef and Horses Graves from 1995–2010. Without their fieldwork various aspects of this thesis would not have been possible; their vital roles will be acknowledged in co-authorships of the forthcoming series of papers. I was responsible for the analysis and writing of each chapter. I discussed some of the fundamental ideas with my supervisors, Les Underhill, Rob Simmons and Jean-Paul Roux. Les Underhill (and to some extent, Jean-Paul Roux and Rob Simmons) advised on methods of data analysis. All three supervisors assisted with the wording of some methods sections and commented on chapter drafts. Jessica Kemper, Rod and Sigi Braby, Res Altwegg, David Wiggins, Teresa Catry, Nicole Braby, Rene Navarro, Mariette Wheeler and Katrin Ludynia commented on some of my chapter drafts. Res Altwegg assisted with the analysis and drafting of Chapter 4 and 5 and will be acknowledged in co-authorship for those papers. Katrin Ludynia conducted the bomb calirometry work for Chapter 6. Maps for all chapters except one were constructed by Holger Kolberg. The maps in Chapter 8 were constructed by Chris Bartholomeau. Photographs not taken by me were credited accordingly.

The planned co-authorships for the papers are outlined below.

Chapter 2: Braby J, Braby RJ, Braby SJ, Simmons RE, Underhill LG, Roux JP and Kolberg H. Clutch size and breeding success of Damara Terns in Namibia.

Chapter 3: Braby J and Underhill LG. Growth patterns, fledging period and feeding rate of Damara Tern chicks in Namibia.

Chapter 4: Braby J, Braby SJ, Braby RJ and Altwegg R. Immature survival and age at first breeding of Damara Terns: conservation from a non-breeding perspective.

Chapter 5: Braby J, Braby SJ, Braby RJ and Altwegg R. Annual survival and dispersal of a seabird adapted to a stable environment: implications for conservation. Submitted to Journal of Ornithology.

Chapter 6: Braby J, Underhill LG and Simmons RE. Prey capture success and chick diet of Damara Terns in southern Namibia..

Chapter 7: Braby J, Underhill LG, Simmons RE and Roux JP. The impacts of diamond mining activities on breeding Damara Terns in southern Namibia.

Chapter 8: Braby J, Braby RJ, Braby N and Simmons RE. 2009. Protecting Damara Terns from recreational disturbance in the Namib Desert increases breeding density and overall success. Ostrich 80: 71–75.

Chapter 9: Braby J, Braby RJ, Braby SJ, Simmons RE, Kolberg H, Braine S, Loutit R, Whittington P, Tree T, Underhill LG, Cooper J, Boorman M, Lonser J, Bartlett P, Kemper J and Roux JP. Population estimates, distribution and conservation of breeding Damara Terns.

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I would like to thank all the staff at Namdeb for the incredible support they provided me while I was conducting field work in isolated and almost inaccessible areas. Namdeb provided me with logistical support, office space, email access, phone lines, accommodation and much more. They provided me with an incredible and reliable vehicle which made it possible for me to access areas that are extremely difficult to get to. I kindly thank Alex McKay for taking the initiative in contacting Les Underhill about getting a student to conduct research and recommend conservation measures with regard to diamond mining for the Damara Tern in the Sperrgebiet.

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Chapter 1

Introduction

INTRODUCTION

Introduction

The study species of my thesis, the Damara Tern *Sterna balaenarum*, is a small desert-breeding seabird found off the coast of south-western Africa that faces several conservation issues. There are many gaps in our knowledge of the species that prevent efficient planning of the protection strategies that could ensure its continued survival. This thesis aims to fill these gaps.

This introductory chapter provides the overall background to the thesis. The Damara Tern is described and compared with the ecology of the six other small terns. Previous research and available literature on the species are summarized. The harsh desert environment of the study area, the Namibian coast, is introduced. Detailed descriptions are given for the study sites where most field work was done and the bulk of the data were collected. Finally, this chapter describes the general layout of each chapter and its aims.

The study species

The small terns

Closely related to gulls (Laridae), terns (Sternidae) are a cosmopolitan, highly homogenous group (Gochfeld and Burger 1996). Compared to gulls, terns are more specialized in terms of nesting habitat, diet and foraging methods, and morphology (Gochfeld and Burger 1996).

Forty-four species are recognized in the tern genera, of which a third are black-capped terns of the genus *Sterna*. The very small *Sterna* terns, once placed in a separate genus *Sternula*, have a mass of less than 70 g (Gochfeld and Burger 1996, Table 1.1).[1] These are small versions of typical terns. With the exception of the Damara Tern, they have a yellow bill with or without a black tip (Gochfeld and Burger 1996). These seven small terns are the Damara, Fairy *S. nereis*, Little *S. albifrons*, Saunder's *S. saundersi*, Least *S. antillarum*, Yellow-billed *S. superciliaris* and Peruvian *S. lorata* Terns (Table 1.1).

Although all the seven small terns feed on small fish by plunge-diving and contact dipping and primarily rely on aquatic organisms, some, including the Little, Least, Saunder's and Yellow-billed Terns, also feed on insects (Table 1.1). Most of the small terns are of Least Concern within international conservation rankings (IUCN 2009). Those that are in need of protection due to their ranking (e.g., the Damara Tern is listed as Near-Threatened, the Peruvian Tern as Endangered) are placed in these categories because of small and declining populations coupled with poorly known status (Gochfeld and Burger 1996). Least and Little Terns have populations breeding on inland rivers and the Yellow-billed Tern is strictly a riverine species; the others breed along the coastlines of islands and the mainland. The Damara and Peruvian Terns predominantly breed on desert plains on the mainland (e.g., Simmons and Braine 1994 for Damara Tern, Zavalaga *et al.* 2008 for Peruvian Tern, Table 1.1), sometimes up to 11.5 km inland (Damara Tern; Braby *et al.* 2001). All have similar breeding and feeding ecologies (Table 1.1). The Peruvian and Damara Tern are nearly identical in most aspects (Table 1.1). Human disturbance and high predation rates are the most common causes of failure in the breeding success of all the small terns (Table 1.1).

[1] These seven terns are regarded by many as *Sternula* presently (Bridge *et al.* 2005).

The Damara Tern

Morphology of the Damara Tern

One of the smallest members of the family Sternidae, the Damara Tern has an average mass of 52 g (Simmons 2005a, Table 1.1). It is less than one twelfth the mass of the largest tern, the Caspian Tern *Hydroprogne caspia* (average mass 690g, Gochfeld and Burger 1996). Similar in size to the other small terns, it can be distinguished by its black, slightly curved bill and overall grey plumage with a white underside. When in breeding plumage it has a black cap that becomes mottled grey with a white forehead during non-breeding (Gochfeld and Burger 1996). It is a fast-flying tern with a shallowly forked tail and a wing length of 160–176 mm (Simmons 2005a).

World population estimates and migration patterns

Damara Terns breed in widely dispersed colonies in the largely inaccessible Namib Desert. Consequently, attempts at estimating the world population have been particularly difficult (Simmons *et al.* 1998a). Most of these estimates have been based on breeding populations. In 1978, the global population was estimated to consist of 4000 individuals, 2000 of which were found in Namibia (Clinning 1978). In 1991 the world population estimate increased to 7000 individuals when a single flock of *c.* 5000 birds was found in northern Namibia at the end of the breeding season (Braby *et al.* 1992). Random sampling techniques were devised in 1992 to more accurately assess the population of Damara Terns (Simmons 1993), and in 1998 the population was estimated to be 13500 individuals (Simmons *et al.* 1998a). This was a much greater number than previously estimated (Simmons *et al.* 1998a). The increase is more likely to be attributable to an improvement of knowledge, rather than to genuine increases in the population size.

Because most of the breeding terns are found in Namibia, the Damara Tern is often considered an endemic breeder to the Namibian coast (Crawford and Simmons 1997). However, small breeding populations have been found along the western coast of South Africa (McLachlan and Liversidge 1978) and southern Angola (Simmons 2010). A small breeding population was found in Cape Town in 1928 (Vincent 1946) and in 1978 breeding populations were found as far east as the Sundays River estuary in Algoa Bay in the Eastern Cape (Every 1979, Underhill *et al.* 1980). Breeding populations occur in Angola as far north as Baia dos Tigres (Simmons *et al.* 2006, Simmons 2010). Apart from sporadic and short-term breeding surveys, Angolan populations are poorly known (Brooke 1984, Simmons *et al.* 2006, Simmons 2010).

All but a small fraction leave southern Africa for non-breeding grounds on the west African coast (Simmons 2005a). Birds leave their respective breeding grounds at the end of summer, usually around March, and move northwards along the Namibian coast where they coalesce with other post-breeding birds into larger flocks before migration (Simmons 2005a). Groups then migrate northward to overwinter in countries such as coastal Congo, Benin, Gabon and even as far as Nigeria (Bourdillon 1944, Elgood *et al.* 1973, Wallace 1973), Liberia (Borrow and Demey 2001) and Senegal (Brown 1979).

Breeding adaptation

Damara Terns return to the southern and western coast of southern Africa every year to breed. Breeding usually starts in October and ends latest in June (Simmons 2005a). The majority of Damara Terns nest along sections of the Namibian coastline, on habitats ranging from salt pans, gravel plains, rocky outcrops and dune fields (Simmons *et al.* 1998a). The small breeding populations in Angola and South Africa breed predominantly in gravel and sand slacks between dunes (Randall and McLachlan 1982, Watson *et al.* 1997, Vincent 1946).

Damara Terns typically breed in loose aggregations 3–5 km inland (Simmons 2005a), even up to 8 km (Simmons and Braine 1994) and 11.5 km in extreme cases (Braby *et al.* 2001). Breeding between dunes leaves incubating and brooding terns vulnerable to wind and sand exposure. Shifting sand can pose a problem to incubating terns and there is a record of an egg being covered by 10 cm of sand in one night at a breeding site at Elizabeth Bay (Johnson 1979). Nesting habitat availability is not a limiting factor to breeding population numbers (Randall and McLachlan 1982, Simmons *et al.* 1998a).

Individuals pair up after courtship feeding and locate a suitable nest site (Simmons 2005a). Unlike most other terns, the clutch size of the Damara Tern is predominantly a single egg; less than 1% of all monitored nests have contained two eggs (de Villiers and Simmons 1997). Frost and Shaughnessy (1976) suggested that the small clutch size is largely the consequence of selection for maximum growth rate of young, as a result of the exposed nest site and the risk of predation. Eggs are buff-coloured with a variable patterning of brown spots underlain with lighter brown spots (Randall and McLachlan 1982). The single egg is laid in a nest scrape on the ground (Plate 1). Nest scrapes are sometimes decorated with small shells and pebbles when eggs are laid in gravel, and on hard ground when eggs are laid in salt pans (Simmons and Braine 1994). Both sexes share incubation duties (Clinning 1978). Incubation time varies between 18 and 22 days (Simmons 2005a) and is typical of small terns (Table 1.1). Hatching of the single egg takes place over a period of several hours (Clinning 1978), and chicks move away from the nest site within two to three days of hatching (Simmons and Braine 1994). This is probably an evolutionary strategy to avoid predation (Frost and Shaugnessy 1976). During the first 3–4 days chicks are brooded more or less continuously by a parent (Clinning 1978, Simmons and Braine 1994). Newly hatched chicks are pale fawn coloured, with few dark brown and black spots dorsally, and white below (Frost and Shaughnessy 1976, Clinning 1978). Feet and legs appear yellow, while their bill is black with a prominent egg tooth (Clinning 1978). Once chicks are mobile they can move quite far (up to 2 km within two days, Simmons and Braine 1994). The distance chicks move has been found to be dependent on the level of disturbance (Simmons and Braine 1994). Feathers first emerge on the scapulars and mantle of chicks during the end of the first week (Clinning 1978). The earliest recorded age at which chicks fledge is 20 days (Clinning 1978) and fledged chicks are still considerably smaller at this age than adults, averaging 6 g lighter (Clinning 1978). Chicks are fed until at least two and a half months after fledging (Clinning 1978, Williams and Meyer 1986).

Predation

The chief natural predator of Damara Tern eggs and chicks is the Black-backed Jackal *Canis mesomelas* (Clinning 1978). The Black-backed Jackals found along the coast are generally scavengers, feeding on dead seals and other carcasses along the coastline. This is why the greatest densities of jackals are found near seal colonies. However, they do hunt opportunistically. Other predators include the Pied Crow *Corvus albus* and Kelp Gull *Larus dominicanus* (Simmons and Braine 1994, Braby *et al.* 2001). Because the highest densities of predators occur along the shoreline, inland breeding is hypothesized to be an evolutionary adaptation to avoid predation (Clinning 1978, Simmons and Braine 1994). By nesting in loose aggregations, with considerable distances between nests, breeding terns are expected to be less conspicuous and thus less vulnerable to predation (Clinning 1978). However, they still benefit from the communal "warning system" that breeding colonially affords, because nests are close enough to each other that an incubating bird is aware of the mobbing activities of "neighbours" and flies off to participate in them. Thus when a predator approaches or enters a breeding colony, it is actively mobbed by many of the terns breeding in the colony to deter or distract them from nests in the area (Randall and McLachlan 1982, pers. obs).

Feeding and diet

Damara Terns feed mainly by plunge-diving for food (Frost and Shaughnessy 1976, Williams and Myer 1986, Simmons and Braine 1994), but they occasionally also float on the sea surface beyond the breakers and pick up minute prey (Braby *et al.* 1992) or swoop and pick up prey on mud-flats (Williams and Meyer 1986). Like most of the small tern species, Damara Terns are essentially inshore feeders and usually frequent sheltered bays, estuaries and lagoons (McLachlan and Liversidge 1970). Their diet consists mainly of small fish and crustaceans (Clinning 1978, Simmons and Braine 1994). Food items collected from adults provisioning their chicks and chick regurgitations included needlefish (Belonidae), mullet sp. (Mugilidae) tiny squid (Loliginidae), and Cape Anchovy *Engraulis encrasicolus* (Simmons and Braine 1994), as well as larval blennies (Blennidae) (Clinning 1978). Lengths of fish delivered to chicks vary in length from1.5–12.5 cm and vary in mass from 2–30[2] g, depending on the size of the chick (Clinning 1978). Prey capture success is poorly known, but the few studies that have been conducted (Simmons and Braine 1994, Simmons 2005b) have looked at prey capture success in relation to water turbidity. At a breeding colony in Elizabeth Bay, Simmons (2005b) considered that prey capture success was found to be negatively affected by mining-induced sediment discharge into feeding areas.

Conservation issues

The conservation of Damara Terns poses considerable problems, mainly due to their vulnerability to disturbance during the breeding season (Frost and Shaughnessy 1976, Braby *et al.* 2001, Williams *et al.* 2004). In Namibia and

[2] 30 g is exceptional, and this prey specimen was fed to a 18-day old chick. No average is given for the mass of fish fed to chicks in Clinning's (1978) study.

South Africa the highest density of breeding terns coincides with the highest density of people in both time and space. This poses serious considerations regarding their protection. The most adverse influences on breeding numbers have been the disruption and displacement of breeding sites through public recreation and coastal development (Frost and Shaughnessy 1976, Braby *et al.* 2001, Williams *et al.* 2004). In some breeding areas, Damara Terns may be threatened by diamond mining (Brooke 1984, Simmons 2005b). In their migratory countries, Damara Terns are trapped and eaten or sold for food (Braby 2010, Annex 1).

Recreational disturbance mainly refers to off-road driving in breeding areas. Off-road vehicles have been considered a threat to breeding waders since 1977 (Summers and Cooper 1977), and Damara Terns have been directly impacted by traffic along their breeding grounds (Plate 2). Off-road driving can directly cause egg and chick losses by trampling, or could cause disturbance and stress to breeding birds and their chicks. The South African Minister of Environmental Affairs and Tourism banned the use of ORVs from South Africa's beaches with effect from 21 December 2001 (Williams *et al.* 2004). In the first year after the ban all 11 pairs at a colony of breeding Damara Terns at Struisbay, Western Cape, South Africa, raised a chick to fledging before the end of January, allowing juveniles more time to prepare for northward migration to the non-breeding grounds in West Africa. This was in contrast to before the ban when most nests failed and adults had to relay, prolonging the breeding season to March (Williams *et al.* 2004).

Since banning of vehicles on the beaches of South Africa has been enacted, off-road vehicle driving along the central Namibian coast has increased (R.J. Braby pers. comm.). The Damara Tern breeding grounds, in the past, have been adversely affected by recreational off-road driving, but after conservation measures were taken in the form of fences restricting off-road vehicles from one breeding ground, breeding productivity and breeding numbers increased (Braby *et al.* 2001). More recently however, these conservation measures are under pressure as enforcement along the central Namibian coast is lacking and off-road vehicle drivers have been cutting fences and traversing breeding grounds anyway, despite the restrictions (R.J. Braby pers. comm.).

Coastal development has caused the extinctions of various colonies, both in South Africa (Vincent 1946), and in Namibia (Frost and Shaugnessy 1976, Clinning 1978, R.J. Braby unpubl. data), and continues to threaten important breeding colonies between the two main coastal towns of Namibia, Swakopmund and Walvis Bay (R.J. Braby pers. comm.).

Diamond mining occurs mainly on the southern coastline of Namibia and the north-western coastline of South Africa, although small-scale mining and prospecting occurs along the coastline of northern Namibia as well. Profitable mineral deposits here could result in large-scale mining (Clinning 1978). Although these areas are protected and largely isolated through public access restrictions, breeding terns have been negatively affected by diamond mining in the past, mainly by sediment discharge into their feeding grounds (Simmons 2005b). Diamond mining could of course directly negatively affect breeding grounds if mining (excavations, dune-stripping, developments etc) were to be conducted on breeding grounds.

The Damara Tern is currently listed as Near-Threatened owing to its moderately small population (which is currently estimated at 13500 individuals, Simmons *et al.* 1998a, IUCN 2009). If the population is found to be undergoing a decline, the species may qualify for uplisting to a higher threat category. In most migratory countries protection laws for the Damara Tern either do not exist, or are weakly enforced. Very little is known of the breeding population in Angola. Angola is signatory to the Convention on Migratory Species (CMS entered into force in Bonn in 1983), which legally binds Angola to create laws protecting species like the Damara Tern. However, these national laws currently do not exist. In the Iona National Park, where breeding terns are found, enforcement that should secure their protection, is weak to non-existent (Simmons 2010, R.E. Simmons pers. comm.). In Namibia, the Damara Tern is Near-Threatened (Simmons and Brown 2008) and is considered a "Specially Protected" species under the draft Protected Areas and Wildlife Management Bill. In South Africa it is Endangered because of low and decreasing numbers (Barnes 2000).

The study area

The Benguela Upwelling System

The Benguela Current is the eastern boundary current of the South Atlantic (Shannon 1989, Peterson and Stramma 1991, Wedepohl *et al.* 2000). It begins as a northward flow off the Cape of Good Hope and moves equator-ward along the south-west African coast until around 24–30°S (Gyory *et al.* 2009). The southern part of the Benguela system is bounded to the south by the warm retroflection zone of the Agulhas Current and is different meteorologically from most other current systems (Shannon 1989). However, the oceanography of the northern Benguela has much in common with its equivalent in the South Pacific, the Humboldt Current (Shannon 1989). Crawford *et al.* (2006) compared and contrasted the seabird assemblages between these two upwelling systems.

The typical sea surface temperature (SST) of the Benguela is 13–15°C, but this varies both seasonally and spatially (Shannon 1989). Off the coast of Namibia there is a definite seasonal temperature cycle (Shannon 1989). Just as there are seasonal changes so are there changes from year to year

(Shannon 1989). A noteworthy phenomenon that can be encountered in the Benguela system is the Benguela Niño (Gyory *et al.* 2009). Benguela Niños can be caused by anomalous atmospheric conditions in the western tropical Atlantic (Boyer *et al.* 2000). Every year there is a south-ward intrusion of warm Angolan water into the northern Benguela, but during a Benguela Niño the Angola-Benguela front is displaced south, causing the movement of warm, highly saline water as far as 25°S (Shannon *et al.* 1986, Boyer *et al.* 2000). During Benguela Niños heavy rains may fall over adjacent desert or escarpment regions (Shannon 1989).

Phytoplankton, the basis of the marine food chain, needs light to grow. This is why, in the sea, most biological productivity takes place in the upper layers (Shannon 1989). The important physical process on the shelf of the Benguela is coastal, wind-induced upwelling. This upwelling brings deep, cold, nutrient-rich water to the surface where there is abundant light. Once oxygenated at the surface, this in turn creates the conditions for the growth of phytoplankton. Because the prevailing wind along the western seaboard of southern Africa is southerly or alongshore, conditions are favourable for upwelling along the entire coast as far as southern Angola (Shannon 1989). However, the upwelling rate is not uniform along the entire coast as the upwelling-favourable winds are stronger in some areas (Shannon 1989). Other factors that influence the rate of upwelling are the effects of topography on wind direction, and the depth and width of the continental shelf (Shannon 1989). The biggest upwelling cell occurs near Lüderitz where the region is windier, colder and more turbulent than elsewhere in the Benguela (Shannon 1989). Preferred habitats for a number of species tend to exist downstream of this upwelling cell. Called "delayed blooming", the plants "bloom", consume nutrients, die and release nutrients (Shannon 1989, Simmons and Cordes 2000). This process is speeded up in warm, oxygenated water and occurs rapidly in semi-closed regions such as near Walvis Bay

(Shannon 1989). The high productivity results in large populations of fish and other marine life which creates the ideal conditions for breeding seabirds like the Damara Tern.

The Namibian coast

The coast of Namibia extends 1570 km from the Cunene River (17°14S, 11°45E, Angolan border) in the north to the Orange River (28°36′S, 16°27′E, South African border) in the south (Figure1.1). The Cunene and Orange Rivers, which form the northern and southern boundaries of Namibia, are the only perennial rivers along the coast.

The coast is relatively straight and lacks indentation apart from two large bays, Walvis Bay and Lüderitz Bay, and a number of smaller inlets (Molloy 2003). The coastline falls within the ancient Namib Desert, which pre-dates the two-million-year-old Benguela Current by tens of millions of years. It is thought to be one of the oldest deserts in the world (65–70 million, Molloy 2003). Rainfall is very low at 15–20 mm per year and only during periods of good inland rains do ephemeral rivers reach the sea (Molloy 2003). Fog is a common occurrence on the coast. The fog belt can extend 20–50 km inland and is essential to the survival of plants and animals along the coastal belt (Molloy 2003).

The five coastal towns, Hentiesbay (4 000 inhabitants), Swakopmund (28 000), Walvis Bay (45 000), Lüderitz (16 000) and Oranjemund (10 000), account for the entire human coastal population. Together, these towns form a small proportion (*c* 5%) of the total national population of Namibia of 2.1 million people (Molloy 2003, World Bank 2009). Because most of the coastline is a desert, and falls into one or other of the restricted conservation or mining areas, there is virtually no rural way of life on the coast (Molloy 2003).

The area extending from the Cunene River to the Ugab River is the Skeleton Coast Park (Figure 1.1). The area between the Ugab River and south of Walvis Bay is the recently proclaimed Dorob National Park, which is heavily used during holiday periods (Figure 1.1). From south of Walvis Bay to north of Hottentots Bay is the Namib-Naukluft Park (Figure 1.1). Finally, from north of Hottentots Bay to the Orange River is the restricted diamond area, under the control of Namdeb; the area was proclaimed the Sperrgebiet National Park in 2009 (Figure 1.1). The coastal waters of Namibia and its islands were given protection in 2010 by the declaration of the Namibian Islands Marine Protected Area (NIMPA) (Ludynia and Kemper 2010) . The provisionally-named Namib-Skeleton Coast National Park is a mega-park which includes all parks (Skeleton Coast, Dorob National Park, Namib-Naukluft Park, Sperrgebiet National Park and the NIMPA) (Tarr 2009). It will be the eighth largest protected area in the world. It will form transfrontier parks with Iona National Park in southern Angola and the Ai-Ais/Richtersveld Transfrontier Conservation Area (Tarr 2009).

The Skeleton Coast Park (SCP, northern Namibia)

The coastline of the Skeleton Coast Park is approximately 495 km long, extending from the Cunene River (17°14S, 11°45E) on the Angolan border to the Ugab River (21°11S, 13°37E) in the south (Figures 1.1 and 1.2). Breeding habitat consists of gravel and rocky plains of various colours (e.g. white, pink, purple and black), salt pans and dunes. Annual rainfall averages less than 20 mm and fog is common (van der Merwe 1983). Vegetation is scarce but *Salsola* sp. hummocks occur as well as scattered plants of *Arthrerua leubnitziae* and *Zygophyllum stapfii*. There are various small and large colonies of breeding terns in the Skeleton Coast Park, but only a few records and limited data were collected here from a variety of colonies and single pairs along the coastline. However, three colonies were of significance, namely Möwe Bay Airstrip (S19°22 E12°43), Huab (S20°50 E13°26) and Ogden Rocks (S24°22 E24°42, Figure 1.2). All of these areas consist of gravel plains.

The Dorob National Park (DNP, central Namibia)

Ugab River to Swakopmund

The coastal area extending south of the Ugab River to Swakopmund forms part of the Dorob National Park and consists of gravel plains sloping upwards from a narrow belt of 1–2 m high *Salsola* sp. hummocks immediately inland of the beach. The only permanent vegetation on these plains is scattered plants of *Arthrerua leubnitziae* and *Zygophyllum stapfii* (Giess 1968). In some areas there is considerable growth of lichens of two species, whilst in other areas barren dry salt pans occur. Data were sporadically collected from various Damara Tern breeding colonies in this area. However, two colonies were of significance, namely Durissa Bay Pans (S21°15 E13°41), which consists mainly of salt pans, and White Stones (S21°39 E13°58), which consists of sparsely vegetated gravel plains (Figure 1.3).

Swakopmund to Walvis Bay

Two important tern colonies are described for this area (Figure 1.3, Plate 3).

(a) *Horses Graves*

The Horses Graves colony covers 2.5 km^2 and occurs in the hyper-arid Namib Desert with a rainfall of less than 15 mm per year (Günster 1995, Mendelsohn *et al.* 2003). It is located 4 km south of Swakopmund (S22°42 E14°33, Figure 4.1 in Chapter 4, Plate 3). The study area is 3.7 km NNE of the Caution Reef colony and comprises a series of barchan, linear, and crescent dunes separated by gravel plains in which the terns breed (Braby *et al.* 2001). Gravel plains are comprised of approximately 3 mm diameter, grey-coloured substrate, with little wind-blown material. By contrast the dunes have a much smaller sand particle diameter and sand transport during prevailing south-westerly winds could be high. The area is situated just south of a disused railway line, 3 km east of the sea, and runs parallel to the coast. The areas used by the breeding terns are devoid of vegetation.

(b) *Caution Reef*

Caution Reef, more commonly known as Patrysberg, is situated 8 km from Swakopmund (22°44S, 14°32E, Figure 4.1 in Chapter 4, Plate 3). The main road to Walvis Bay cuts across the breeding area. The area west of the road extends 2 km north to south and 1 km east of the sea. The area east of the road extends up to 600 m towards the high dunes (Braby *et al.* 2001). The habitat at Caution Reef consists mainly of open and sparsely vegetated sandy plains with a raised gravel ridge through the centre (Braby *et al.* 2001).

<u>The Namib-Naukluft Park</u>

This area consists mainly of vast expanses of dunes and dune fields. The area is protected and virtually inaccessible, although tourism concessions are given to tour operators. Few data were collected at colonies in this area, of which the main colony is Meob Bay (S24°22 E24°42, Figure 1.4). Meob Bay consists of extensive gravel plains backed by vast expanses of sand dunes.

<u>The Sperrgebiet National Park (SNP)</u>

The "Sperrgebiet", directly translated from German as "restricted area", is owned by Namdeb Diamond Corporation (Pty) Ltd and was proclaimed the

Sperrgebiet National Park in 2009 (Tarr 2009). It extends from the southern border of Namibia to north of Hottentots Bay (26°00′S, 15°58′E, Figures 1.1 and 1.5). Along this coastline, four main colonies exist: Hottentots Bay (26°14′S, 14°59′E), Grosse Bucht (26°43′S, 15°40′E), Elizabeth Bay (26°55′S, 15°14′E) and Marmora Pan (27°45′S, 15°34′E). Data were collected from these four colonies.

(a) *Hottentots Bay*

The breeding colony at Hottentots Bay is found on Anigab Pan (26°14′S, 14°59′E, Figure 7.1 in Chapter 7) which extends 20 km north to south and up to 5 km at its widest part. It is enveloped by rocky outcrops and mountains on the west side, dunes on the east side, vegetated dunes on the south side, and Hottentots Bay on the north side. The pan comprises pure salt, brown salt crusts and extinct lagoon molluscan fauna. The large areas of molluscan shells that are found on the salt flats today may date from the mid-Holocene marine transgression and the development of a short-lived tidal marsh (Kinahan and Kinahan 2002); subsequent lowering of the mean sea level has placed the lagoon beyond the reach of the normal tidal range and thus the entire pan is dry for most of the year. During spring tide some areas may become flooded; these areas are linked to the sea through channels between the western mountains and rocky outcrops (Figure 7.1 in Chapter 7).

(b) *Grosse Bucht*

Grosse Bucht is a bay found within the recreational area along the Lüderitz Peninsula and is about 2.5 km wide (Figure 7.1 in Chapter 7). The Lüderitz Peninsula is accessible to the public. This bay is surrounded by rocky outcrops on either side and is hugged by *Salsola* sp. hummocks. A salt pan can be found directly north and parallel to the bay at a distance of 800 m from the sea. Breeding Damara Terns are found within this salt pan (26°43′S, 15°05′E). The salt pan comprises pure salt, brown salt crusts and areas of loose gravel and sparse vegetation and is approximately 500 m wide and 500 m long.

(c) *Elizabeth Bay*

Elizabeth Bay is about 4 km wide, with a rocky promontory known as Elizabeth Point forming the western arm, and rocky shores backed by sand dunes of the southern Namibian desert forming the eastern shoreline (Figure 7.1 in Chapter 7, Pulfrich *et al.* 2003). Possession Island, 8.5 km to the south of Elizabeth Point, offers the bay limited protection from the prevailing westerly to south-westerly Atlantic swells. Directly to the north-east of Elizabeth Bay is a channel comprised of salt pans and gravel plains, most of which have been heavily disturbed by diamond mining operations. To the south-east of Elizabeth Bay is an extensive area of sand dunes which reach the shoreline on the eastern side of the bay.

(d) *Marmora Pan*

Marmora Pan is situated 140 km south of Lüderitz (Figure 7.1 in Chapter 7). It is 10 km north of a mining site that has stopped production and was rehabilitated in 2007. The pan is 7 km long and 5 km wide and is partly covered in sand dunes. The pan is made up of soft brown salt crusts and sand dunes in the south, hard brown salt crusts in the north. There is no pure salt on the pan and prevailing southerly winds regularly blow dune sand over the surface.

The structure and overview of this thesis

Because the Damara Tern has a restricted distribution and faces several anthropogenic threats, an increased and updated knowledge base of the species is critical to helping us construct necessary conservation strategies. This thesis presents information on the ecology and numbers of the Damara

Tern, most of which was previously unknown. It also outlines the conservation implications of these findings, and suggests ways forward. It comprises four sections and 10 chapters. **Chapter 1** reviews current knowledge of the species, and provides an overview and introduction to the thesis.

Section I investigates and discusses the breeding biology of the Damara Tern and consists of two chapters:

Chapter 2 updates previous information regarding clutch size, egg measurements, incubation periods using larger sample sizes, describes the breeding success, and the causes of nest losses of breeding Damara Terns in Namibia.

Chapter 3 discusses growth, fledging and feeding rate of Damara Tern chicks in Namibia.

Section II of this thesis investigates the life-history parameters of the Damara Tern at two colonies in Namibia and puts this within a conservation perspective; it consists of two chapters:

Chapter 4 investigates age at first breeding and immature survival of Damara Terns by using multi-state capture-mark-recapture models. It uses data of ringed nestling and adult individuals at two breeding colonies in central Namibia, and discusses the implications of these from a conservation perspective.

Chapter 5 discusses the dispersal and adult survival probabilities of Damara Terns breeding at two colonies in central Namibia. Multi-state capture-mark-recapture models were used to estimate annual adult survival at the two colonies, and the annual movement probabilities between them, while accounting for the recapture probabilities at both colonies. The findings of the study are put in a conservation context.

Section III investigates the feeding ecology and chick diet of the Damara Tern and consists of one chapter:

Chapter 6 investigates the prey capture success and the composition of chick diet of the Damara Tern in southern Namibia and addresses the following research question:

- Does prey capture success in the Damara Tern differ according to environmental condition and habitat?

It aims to address this question by measuring the prey capture success of the Damara Tern under the following environmental conditions: tidal phase, wind strength, water clarity, cloud cover, water depth and location.

Section IV of this thesis investigates anthropogenic disturbances and conservation of the Damara Tern using two case studies and then discusses the population and overall conservation of the species; it consists of three chapters:

Chapter 7 investigates the impacts of diamond mining on the prey capture success and breeding productivity of the Damara Tern in southern Namibia. It specifically aims to address the following question:

- Does increasing sediment into a bay where Damara Terns feed affect Damara Tern prey capture and breeding success?

This chapter addresses this question by comparing the prey capture success, chick condition, breeding success and colony size of Damara Terns at the mined colony with the nearest un-mined colonies.

Chapter 8 investigates the protection of a Damara Tern breeding colony from off-road vehicles and addresses the following question:

- Does restricting access for off-road vehicles from Damara Tern breeding areas increase breeding productivity of Damara Terns?

This chapter addresses this question by investigating the breeding productivity of the Damara Tern before and after restrictions to the breeding areas.

Chapter 9 collates published and unpublished data on breeding colonies of Damara Terns in their breeding range, estimates the global breeding population, discusses the threats and conservation and recommends additional survey and conservation measures for the future.

Chapter 10 concludes the thesis by providing an overview and synthesis of findings, and makes recommendations for future research and conservation interventions.

Table 1.1: A comparison of the ecology of the seven small terns of the genus *Sterna*.

	Damara Tern *S. balaenarum*	**Peruvian Tern** *S. lorata*	**Little Tern** *S. albifrons*	**Least Tern** *S. antillarum*	**Saunders Tern** *S. saundersi*	**Fairy Tern** *S. nereis*	**Yellow-billed Tern** *S. superciliaris*
Food and Feeding	Small Fish (e.g. mullet, anchovy), plunge-diving[1, 2]	Small fish (e.g. anchovy), krill, plunge-diving[1]	Small fish, crustaceans, annelids and mollusks, plunge- diving[1]	Small fish, shrimps, marine worms, flying ants, plunge- diving[1]	Small fish, crustaceans, mollusks, insects[1]	Small fish, gastropods, crustaceans[1]	Small fish, shrimps, insects[1]
Conservation Status	Near- Threatened[3]	Endangered[3]	Least Concern[3]	Least Concern[3]	Least Concern[3]	Vulnerable[3]	Least Concern[3]
Breeding Range	Southern Africa, near-endemic to Namibia[1, 2]	Ecuador to Chile[1]	West Africa, Europe, India, Sri Lanka[1]	Florida, Texas, West Indies, California, Carribbean[1]	Karachis and Sri Lanka Red Sea, Gulf of Guinea, East African coast, India, Seychelles, Maldives, Madagascar[1]	South Australia, New Zealand, Tazmania[1]	Brazil, Argentinia, Uruguay, Peru, Surinam[1]
Non-breeding Range	North west coast of Africa e.g. Gabon, Cameroon, Nigeria[1,2]	Unknown[1]	East Africa, West Africa[1]	West-Mexico, Central America, Carribbean, South America, Brazil[1]	Either resident or moves south or east of breeding range[1]	North Australian coast[1]	–
Breeding Period	Oct–Feb, latest June[1, 2]	Oct–Jan[1]	April–June[1]	April–Aug[1]	June–Aug[1]	Sept–March[1]	Nov–July[1]
Adult Mass (g)	46-55[1], 52[2]	45[4]	47–63[1]	39–52[1]	40–45[1]	57[1]	40–57[1]

	Damara Tern *S. balaenarum*	Peruvian Tern *S. lorata*	Little Tern *S. albifrons*	Least Tern *S. antillarum*	Saunders Tern *S. saundersi*	Fairy Tern *S. nereis*	Yellow-billed Tern *S. superciliaris*
Mean Clutch Size	1[1, 2]	2[1]	2–3[1]	2–3[1]	2[1]	2–3[1]	2–3[1]
Mean Egg Size (mm)	32.2 × 23.8[2]	30.9 × 23.5[5]	32.2 × 24.1[6]	31.7 × 22.25[7]	35.5 × 25.3[7]	35.5 × 25.3[6]	30.5 × 23.6[8]
Hatching Mass (g)	6.5[2]	6-7[1]	6.5[1]	6.5[1]	–	–	–
Nesting Habitat	Gravel plains betw dunes, salt pans, sand and gravel plains, up to 11.5 km inland[1]	Gravel plains, broad sandy beaches, sometimes several km inland[1]	Barren/ sparsely veg sandy, shell, rocky beaches, along river banks, marshes, coral islands[1]	Vegetated sandy beaches, gravel bars, mudflats, parking lots, roof tops[1]	Coastlines, estuaries, lagoons, mudflats, high above high tide line, rarely inland[1]	Coral or sandy beaches/islands, extensive coastal dunes[1]	Riverine sandbars[1]
Nest type	Shallow scrape with shells, pebbles[1]	Shallow scrape[1]	Scrape in sand or shell[1]	Scrape in bare sand, rock, shell[1]	Scrape in sand or shell, or animal footprint[1]	Scrape in sand or shell[1]	Shallow scrape[1]
Incubation period (days)	18–23[1, 2]	22–23[1]	21–24[1]	19–24[1]	*c.* 20[7]	20–25[1]	–
Fledging period (days)	20–22[1], 20[2]	24–29[5]	20–24[1]	17–21[1]	*c.* 20[6]	22–23[1]	–
Productivity (young/pair)	0.16–0.35[1], 0.53[2]	–	0.03–0.4[9]	0.2–1.5[1]	–	0.7[1]	1.04[1]

	Damara Tern *S. balaenarum*	**Peruvian Tern** *S. lorata*	**Little Tern** *S. albifrons*	**Least Tern** *S. antillarum*	**Saunders Tern** *S. saundersi*	**Fairy Tern** *S. nereis*	**Yellow-billed Tern** *S. superciliaris*
Sources of nest failure	Black-backed Jackal, gulls, kestrels, human disturbance, flooding[1, 2]	Peregrine Falcon, Grey Fox, Skunk[1]	Gulls, corvids, *Sterna hirundo*, human disturbance[1]	Flooding, human disturbance[1]	Gulls, human disturbance, flooding[1]	Rats, cats, human disturbance[1]	Flooding and human disturbance[1]
Fledging dependency	2–5 months[1], 10 weeks[2]	–	2–3 months[1]	–	–	50 days[1]	–

[1] Gochfeld and Burger 1996, [2] Simmons 2005a, [3] IUCN 2009, [4] C. Guerra unpubl. data [5] Zavalaga *et al.* 2008, [6] Higgins and Davies 1996, [7] Urban *et al.* 1986, [8] Escalante 1970, [9] Cramp 1985

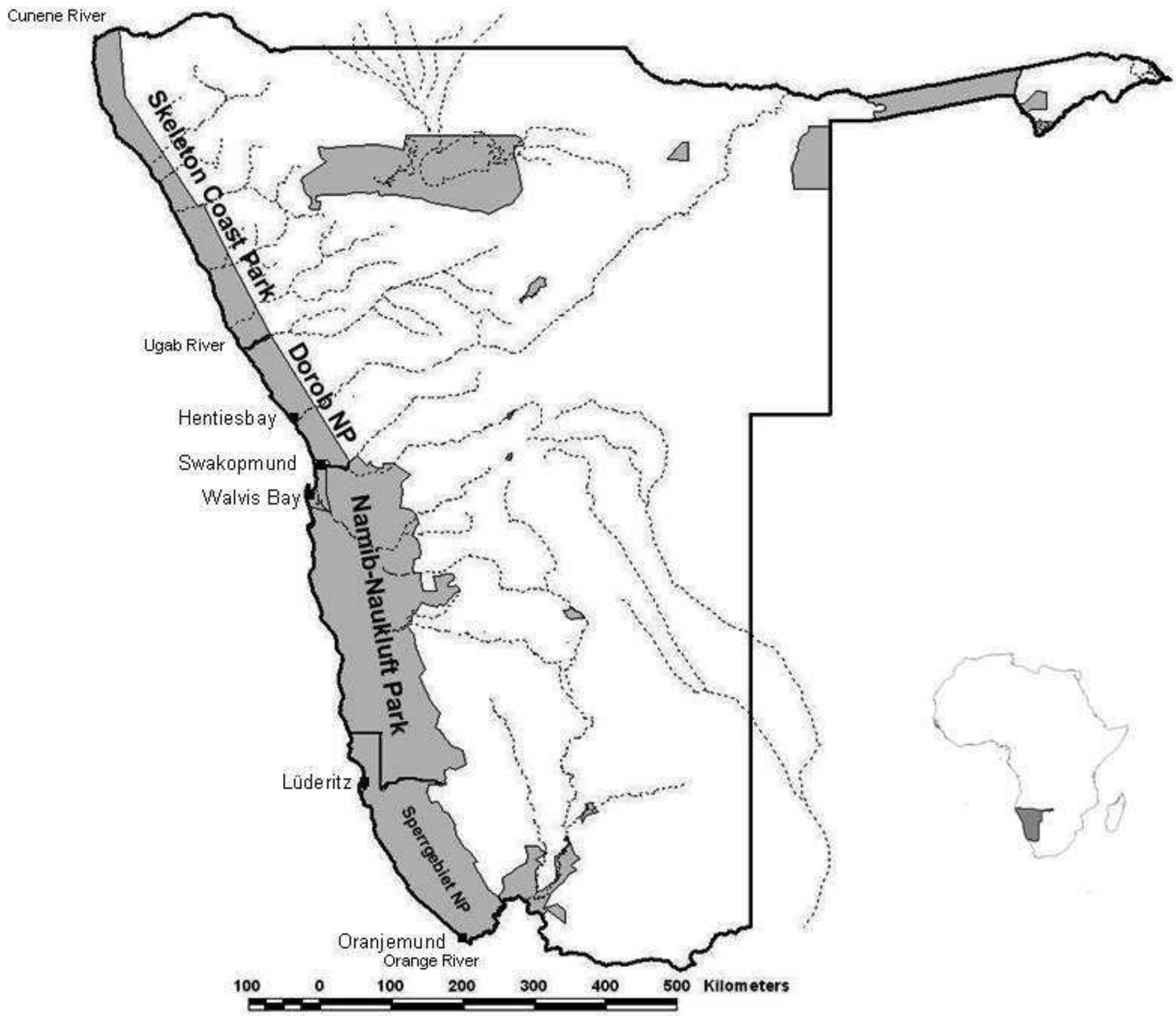


Figure 1.1: Map of Namibia, showing the division of the study area of the thesis (see text) into the Skeleton Coast Park, Dorob National Park, Namib-Naukluft Park, and Sperrgebiet National Park. All areas shaded in grey represent protected areas. Dotted lines represent ephemeral rivers. All major coastal towns are labeled. The Cunene River forms the political border between Namibia and Angola and the Orange River in the south forms the political border between Namibia and South Africa.

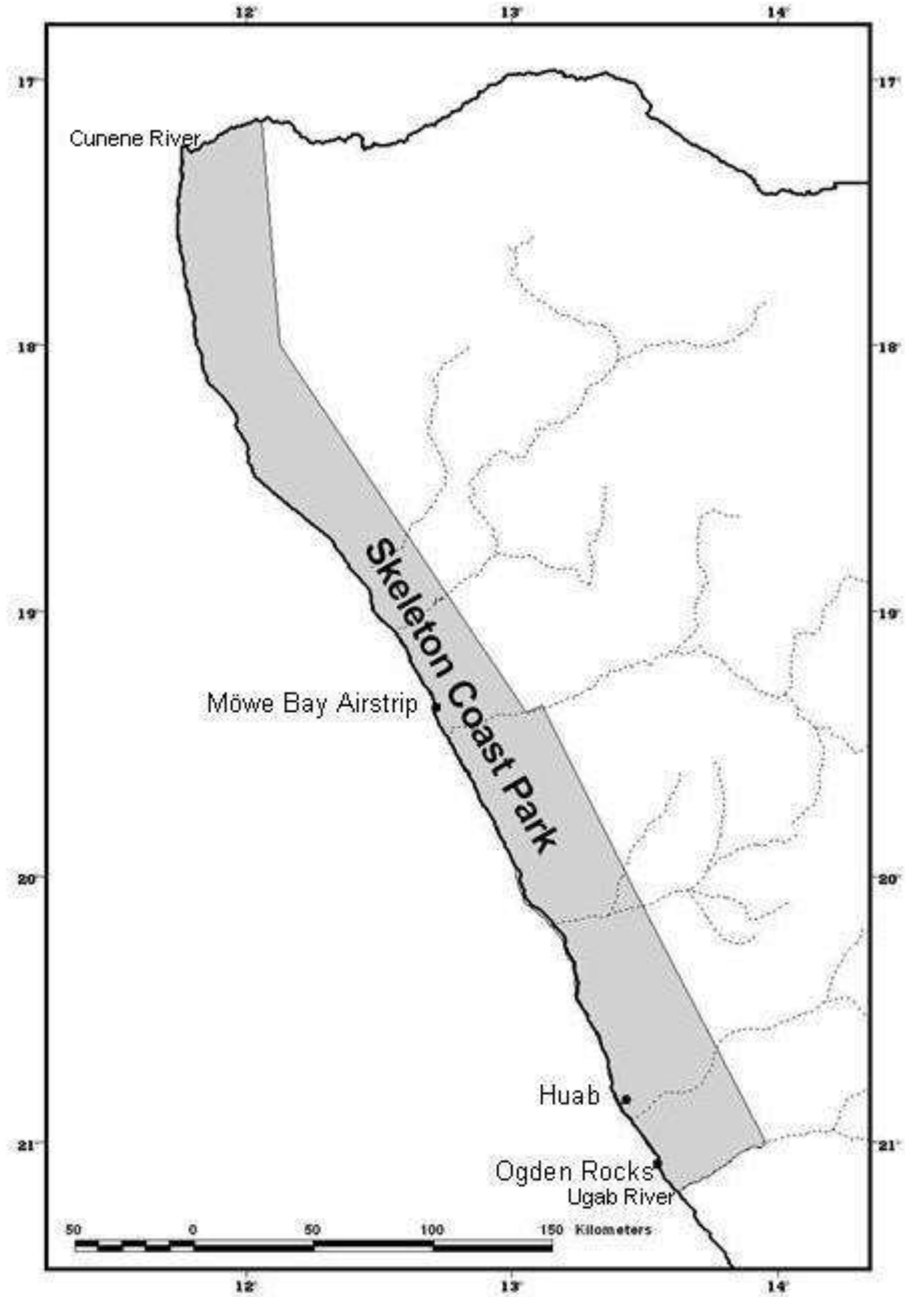


Figure 1.2: Map of the Skeleton Coast Park in northern Namibia, showing the location the three Damara Tern breeding colonies important to this study (see text).

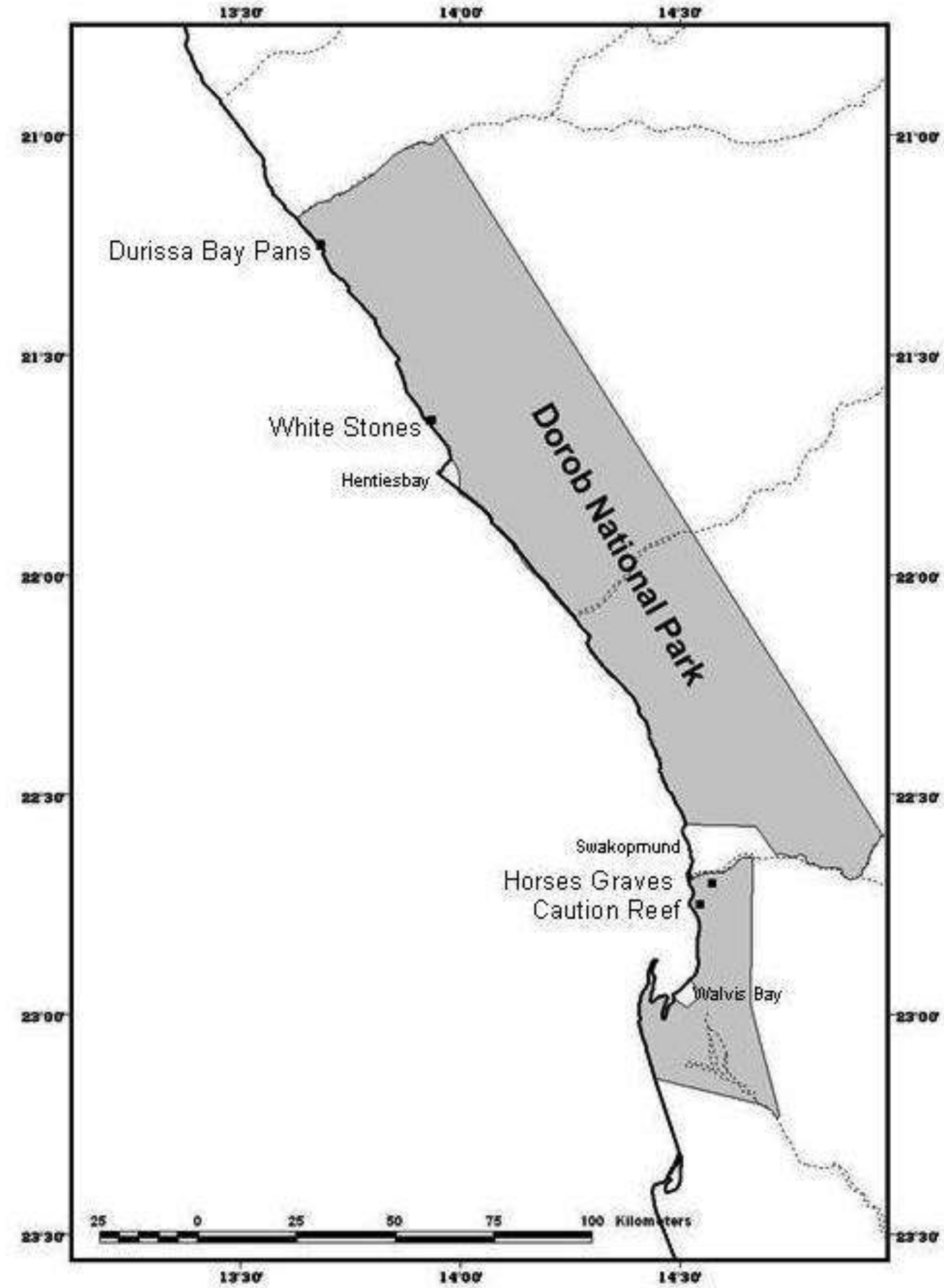


Figure 1.3: Map of the Dorob National Park in central Namibia, showing the locations of the four Damara Tern breeding colonies important to this study (see text). The location of the towns, Hentiesbay, Swakopmund and Walvis Bay are also shown.

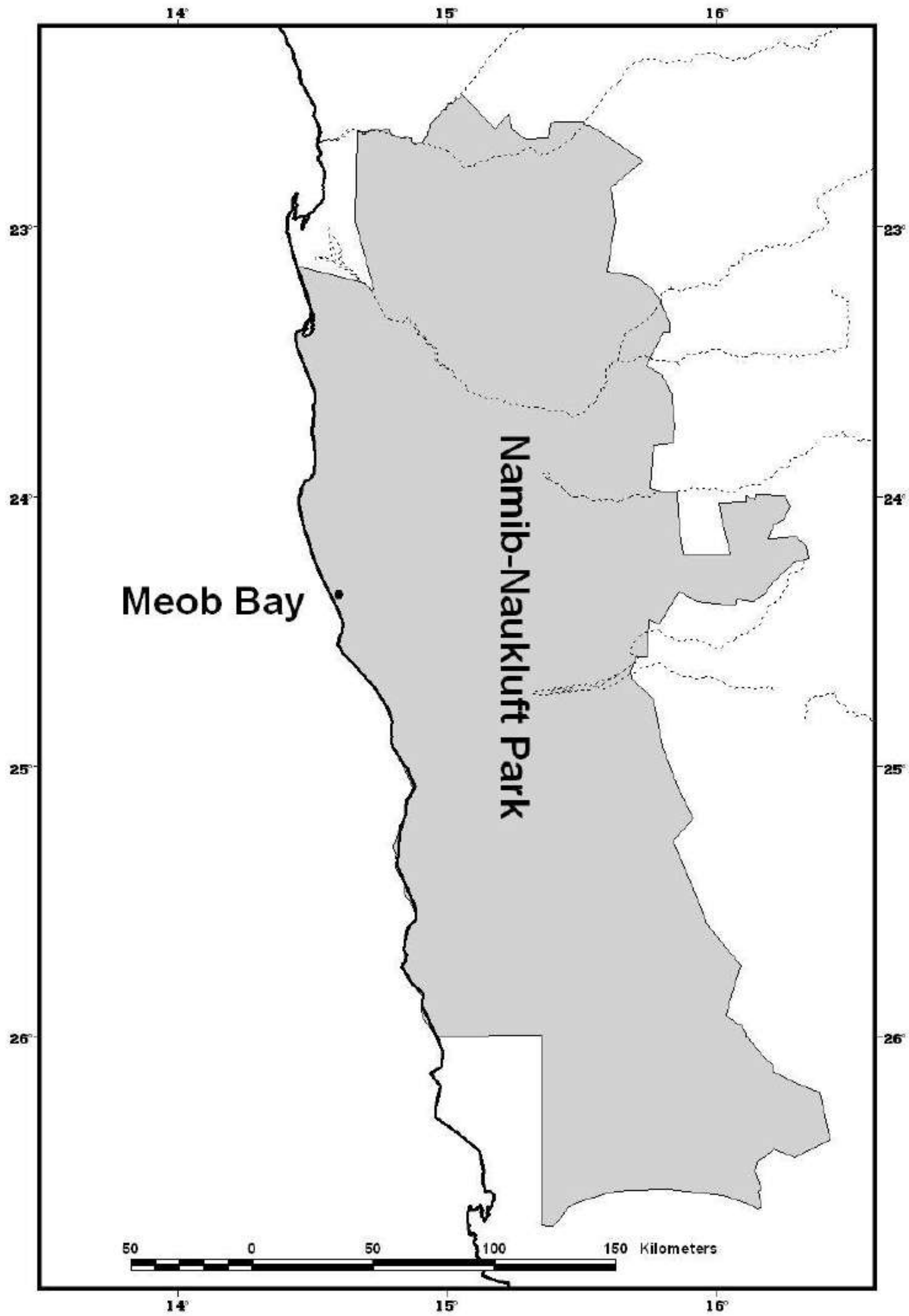


Figure 1.4: Map of the Namib-Naukluft Park in central/southern Namibia, showing the location of Meob Bay, and important Damara Tern breeding colony to this study (see text).

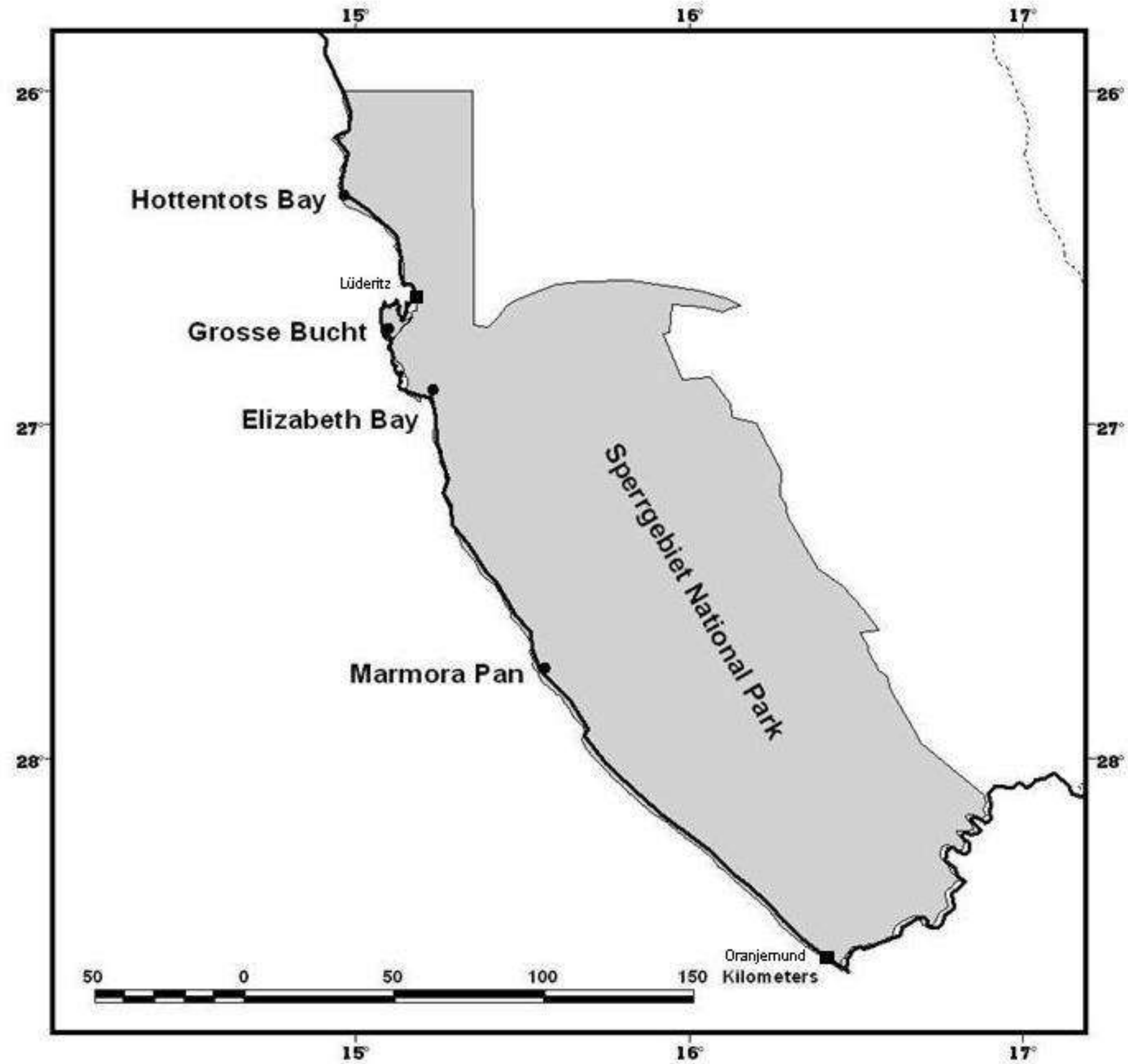


Figure 1.5: Map of the Sperrgebiet National Park in southern Namibia, showing the locations of the four Damara Tern breeding colonies important to this study (see text). The location of the towns, Lüderitz and Oranjemund, are also shown.

Chapter 2

Clutch size and breeding success of Damara Terns *Sterna balaenarum* in Namibia

Kevin Jones

Clutch size and breeding success of Damara Terns *Sterna balaenarum* in Namibia

Introduction

The key parameters in understanding the life history of a species are a knowledge of its reproductive rates, age-specific survival rates and age at first breeding. This chapter discusses the reproductive rates of Damara Terns *Sterna balaenarum*.

Arguably, what sets the Damara Tern most apart from the other small terns is that it lays only one egg (Table 1.1 in Chapter 1). Two-egg clutches are rare, and make up *c.* 1% of all nests recorded in Namibia (de Villiers and Simmons 1997). Generally, reduced clutch-size is associated either with low rates of food availability or high risks of predation (e.g. Lima 1987, Martin 1992, 1996, Hockey and Wilson 2003). The breeding range of Damara Terns is found in an area of high biological productivity (Cushing 1971, Shannon 1989), so Frost and Shaughnessy (1976) thought that food availability is unlikely to be a limiting factor. Predation risk has been hypothesized as the key factor in determining the small clutch size of Damara Terns (Frost and Shaughnessy 1976, Clinning 1978).

Damara Terns breed far inland and nest in loose aggregations (Chapter 1). Inland breeding and nesting in loose aggregations is likely to be an evolutionary adaptation to avoid nest predation (Frost and Shaughnessy 1976), mainly because predators, like the Black-backed Jackal *Canis mesomelas*, generally patrol the beaches (Simmons and Braine 1994). Inland nesting also means that nests are not vulnerable to flooding by high tides. Clinning (1978) suggested that, in light of inland breeding, increased brood size in the Damara Tern would limit the feeding rate and protection each individual young would obtain. However, feeding rates were not obtained in that study. Frost and Shaughnessy (1976) postulated that one-egg clutches in Damara Terns may be a result of selection for faster growth rates of young as a way to overcome the high risk of predation. However, growth rates were not available to compare with those of similar species in order to test this assumption.

The incubation period of Damara Terns is known to mostly range between 18 and 22 days, but can vary from 17.5 to 30 days (Simmons 2005a). Breeding success is not well known and is estimated at 53% in Namibia (Simmons 2005a). This estimate was based on the percentage of fledged chicks in a flock of 4004 post-breeding adults observed in March 1991 in northern Namibia (Braby *et al.* 1992, Simmons 2005a). Nest losses have mainly been attributed to human disturbance, Black-backed Jackals *Canis mesomelas* and gulls (Simmons 2005a).

Many of the aspects of breeding biology of the Damara Tern have been based on small samples sizes (Clinning 1978, Simmons and Braine 1994), and/or focused on specific areas of the Namibian coastline (Clinning 1978, Braby 1995, de Villiers and Simmons 1997). Damara Terns are Near-threatened globally (IUCN 2009) and are "Specially Protected" under the draft Protected Areas and Wildlife Management Bill of Namibia. Colonies are threatened by anthropogenic activities, such as off-road driving (Braby *et al.* 2001, Chapter 8), mining (Connor 1980, Simmons 2005b), and coastal development (R.J. Braby unpubl. data). In light of this, it is becoming increasingly important to update these (and other) aspects with new and detailed information which include various colonies along the entire coastline of Namibia.

The objectives of this study are to (a) update previous information regarding clutch size, incubation period and egg measurements using larger sample sizes, (b) quantify the breeding success, and (c) determine the causes of nest losses of breeding Damara Terns in Namibia. I also review the evolutionary factors determining the clutch-size in this species.

Methods

Study Area and monitoring methods

The study areas and monitoring methods are categorized into three groups:

(a) During 1983–1993 and 19 December 2009–14 February 2010 sporadic visits were made to colonies and singleton pairs found within the Skeleton Coast Park and Dorob National Park (Figure 1.1 in Chapter 1). These visits included finding nests, nest content checks and egg measurements. These areas are referred to as "north".

(b) In central Namibia (in the Dorob National Park), Horses Graves (S22°44 E14°32) and Caution Reef (S22°42 E14°33) were monitored for 10 consecutive years, during breeding seasons 2000/01 to 2009/10 (Figures 1.1 and 1.2 in Chapter 1). Length of monitoring varied according to length of breeding season, but usually began in September and ended in March. Daily visits included finding new nests, checking nest contents and looking for signs of possible predation if nests were empty. Effort was rarely made to relocate chicks after they successfully hatched. These areas are referred to as "central".

(c) In southern Namibia (in the Sperrgebiet National Park) I monitored four colonies (Figures 1.1 and 1.4 in Chapter 1): Hottentots Bay (26°14′S, 14°59′E), Grosse Bucht (26°43′S, 15°40′E), Elizabeth Bay (26°55′S, 15°14′E) and

Marmora Pan (27°45′S, 15°34′E). Monitoring took place during 15 January–31 March 2007, 22 September 2007–31 March 2008 and 1 October 2008–31 March 2009. Visits to each colony included observing adults, finding new nests, checking nest contents, measuring eggs, re-locating chicks that had left the nest, and finding signs of nest/chick losses (e.g. empty nests led to searching the vicinity for mammal tracks or other predator clues). Because of logistical reasons, more time was available to monitor the colony at Hottentots Bay in 2008/09 than in 2007/08 (414 hours were spent monitoring at Hottentots Bay in 2008/09 versus 202 hours in 2007/08). The other three colonies received the same time and search efforts over both seasons. These four areas are referred to as "south".

At all three coastal areas, chicks were ringed with SAFRING stainless steel rings (2.8 mm internal diameter).

Egg measurements and incubation

Egg dimensions (length and breadth, mm) were measured using Vernier calipers to the nearest 0.1 mm (measurements from 1983–1993) and digital calipers to the nearest 0.01 mm. Egg masses (g) were taken using both a 10 g Pesola scale (for eggs less than 10 g), and a 100 g Pesola scale. Egg volume (cm^3) was estimated from the equation

$$volume = 0.000476 \times length\ (mm) \times breadth^2\ (mm)$$

as described by Bolton (1991). Incubation periods (days) were estimated for nests with known laying and hatching dates. Laying dates were determined by:

1. The observer observed a female laying her egg (i.e. there was no egg in the empty scrape before).

2. If the area was visited daily and the observer noticed a pair in the area looking like they were going to nest, and on the next day there was a nest with an egg.
3. If the area was visited daily, and the observer had not seen the nest the day before, and was certain that the nest had not existed the day before.

The maximum error associated with determining laying date was one day.

Breeding success and number of nests

Generally, nests in the north and central areas were monitored only up to the time of hatching and not during the fledging period because of the difficulty of relocating cryptic and mobile chicks. Attempts to monitor nests until the chick fledged or the nest failed were only made in southern Namibia. However, even in southern Namibia nests (or mobile chicks) were not always found again and evidence of any predation (or other cause of death) was not always available. Hatching and fledging success was therefore estimated using the approach developed by Mayfield (1961, 1975) and extended by Underhill (submitted). The extended Mayfield method enables explanatory variables to be incorporated into nest success modeling using the standard hypothesis testing and model selection approaches used, for example, in generalized linear models. Model fitting was undertaken using the RSURVIVAL procedure of GenStat (GenStat 12 Committee 2009). For comparative reasons, one colony would be set as the baseline level.
The modelled probability of breeding success was then calculated using the inverse of the logistic transformation from the parameter coefficient. Explanatory variables used were coastal area (i.e. north, central, south), breeding colony and breeding season. On average, Damara Terns incubate for 23 days (this Chapter) and chicks fledge 23 days after hatching (Chapter 3). Nest days of infertile/addled eggs were counted as long as the adult was

incubating, and infertile/addled eggs were ultimately deemed as failures. Infertile/addled eggs were defined as eggs which were either not fertilized or failed to hatch because of some deformity during egg production. This generally meant that the parents would incubate while the egg failed to hatch. If an egg was abandoned, it was deemed as a failure. If the egg was predated, it was deemed as a failure. Eggs were defined as predated if:

1. There was direct evidence of predation; i.e. predators were seen taking eggs, tracks were found leading up to empty nests or shell fragments were found.
2. Eggs in initial stages of incubation disappeared, or observer knew that the egg would not have hatched yet and it had subsequently disappeared.

All eggs which failed to hatch due for any reason, were deemed as failures. All chicks which failed to fledge were defined as failures. Chicks were determined as having been predated if:

1. There was direct evidence of predation; i.e. tracks were found around nest area and chick was still at hatchling stage.
2. Chick disappeared and even after daily searching was never found again and the colony searched was small, e.g. Grosse Bucht. Searching would include laying low and waiting for adults to come with fish to feed their chick.

If chicks disappeared, but it was not certain if they were predated or survived, their fate was deemed as unknown (i.e. no failures were observed and only nest days where the nest/chick was observed were counted).

I investigated the relationship between the Southern Oscillation Index (SOI) and the observed number of Damara Tern nests during each breeding season at Horses Graves and Caution Reef. The Southern Oscillation Index (SOI) represents a combination of climate measures, and a high SOI relates to high marine productivity (Durant *et al.* 2010). Monthly SOI data was obtained from the Australian Bureau of Meteorology (http://www.bom.gov.au/climate/current/soi2.shtml), and the values for September, October and November were averaged to form a Spring SOI value for each year. This is the period during which Damara Terns would be evaluating whether to breed in a particular breeding season. The relationship was modelled using a generalized linear model with a Poisson distribution for the number of nests each season, and with Spring SOI as the explanatory variable.

Nest failures

Nest failures were observed in the north, central and south of Namibia. Evidence of predation (at egg or chick phase), such as tracks leading up to empty nests, or seeing predators take eggs or chicks, was used to explain nest losses attributed to predators. A nest was defined as abandoned if no adult was present at the nest for more than five subsequent observer visits (each visit ranged between 1 and 5 days apart), and the egg was cold to the touch. An egg was defined as infertile/addled if the adults incubated for periods longer than 45 days.

Apart from monitoring fledging success in southern Namibia, and hatching success in central Namibia, nest failure data were sporadic, erratic and spanned multiple areas. Therefore, it was not feasible to divide failures into various years and colonies.

Results

Clutch size, egg dimensions and incubation period

Of 2528 nests recorded along the coastline of Namibia from 1983 to 2010, five (0.002%) contained a two-egg clutch. Mean length, breadth and volume of 586 eggs from 585 nests, were 33.09 mm (SD=1.1 mm, range=30.55–37.12 mm) and 23.84 mm (SD=0.63 mm, range=21.00–25.80 mm), 8.96 cm^3 (SD=0.59 cm^3, range=6.71–0.81 cm^3), respectively. The mean fresh mass of an egg was 10.17 g (SD=0.58 g, n=12, range=9.3–11.5 g); the mean pipping (egg is starred) mass was 7.92 g (SD=0.57 g, n=68, range=6.5–9.7 g). The mean incubation period was 22.9 days (SD=2.0, n=106, range=19–31 days).

Breeding success and number of nests

The daily rates of nest loss during incubation and fledging periods were not significantly different (for example, likelihood ratio test in central Namibia, with the largest data set, allowing for interyear differences, L=17.1, chi-squared distribution with 17 degrees of freedom, P=0.45). Nest days and chick days were therefore combined in the RSURVIVAL model. The modelled rates were back-transformed (Underhill submitted) to obtain estimates of daily survival probability and raised to the power of 46, the average period (days) from laying to fledging. The breeding success was thus defined as the probability of survival of a breeding attempt from egg-laying to fledging.

A total of 1629 nest were monitored nests, with 21047 incubation days and 11632 chick days. The modelled overall probability of breeding success (BS) in Namibia was 0.356 (95% confidence interval 0.326, 0.387). There was insufficient data to ascertain breeding success at different colonies or for different years in the north. Therefore, breeding success for all colonies and years combined in the north was 0.37 (Table 2.1).

In central Namibia, where two colonies were monitored over 10 seasons, overall breeding success was 0.34 (Table 2.1). Damara Terns breeding at Horses Graves generally had larger breeding success than those at Caution Reef (Table 2.2). There were no significant differences between all breeding seasons at Horses Graves and the baseline of the model (Caution Reef in 2000/01, Table 2.2). Damara Terns breeding at Horses Graves during 2001/02 had the highest breeding success (BS=0.73, P=0.21, Table 2.2). The highest BS at Caution Reef was also in 2001/02 (BS=0.55, P=0.79, Table 2.2). In 2007/08 and 2008/09 at Caution Reef, breeding success was significantly lower than the baseline (2007/08, P=0.02; 2008/09, P=0.01; Table 2.2). These two seasons at Caution Reef also had the lowest breeding success overall (2007/08, BS=0.10; 2008/09, BS=0.08; Table 2.2). Apart from these two seasons, breeding success did not fluctuate significantly between seasons at Caution Reef (Table 2.2). Breeding success also did not fluctuate significantly between seasons at Horses Graves (Table 2.2). Jackal predations were generally associated with low breeding success at both colonies and seasons (Figure 2.1). Jackal predation was more common at Caution Reef than at Horses Graves (Figure 2.1). The number of nests fluctuated between colonies and seasons (give the range), and was largest at Horses Graves in 2002/03.

At both Horses Graves and Caution Reef, there were nine years out of the 10-year period 2001–10 for which counts of the number of nests was available (data were missing for 2000/01 at Horses Graves, and the count for both colonies for 2005/06 was incomplete). The generalized linear model suggested a negative relationship between number of nests and Spring Southern Oscillation Index (SOI) at both colonies (Figures 2.2 and 2.3). The regression coefficient for Spring SOI at Horses Graves was –0.0323 (SE=0.0064, $t_7 = -5.09$, P<0.001) and at Caution Reef was –0.0120 (SE=0.0050, $t_7 = -2.38$, P=0.017). At Horses Graves Spring SOI accounted for 30.8% of the deviance, and at Caution Reef it accounted for 9.3% of the deviance.

In the south, the probability of breeding success for both seasons and all four colonies was 0.44, significantly higher than the other two coastal areas (P=0.009, Table 2.1). Breeding success fluctuated significantly between colonies and between two seasons in the south (Table 2.3). Damara Terns breeding at Hottentots Bay had the highest breeding success for both seasons

(2007/08, BS=0.80; 2008/09=0.56; Tables 2.3 and 2.4). Breeding success at all colonies was significantly lower than the baseline of the model (Hottentots Bay, 2007/08, Table 2.3). Breeding success was lowest at Grosse Bucht in 2007/08 (Tables 2.3 and 2.4). Breeding success was lowest at Elizabeth Bay and Marmora Pan in 2008/09 (Tables 2.3 and 2.4).

Breeding success was significantly higher at Hottentots Bay in 2007/08 than in 2008/09 (P= 0.03, Tables 2.3 and 2.4). Damara Terns breeding at Grosse Bucht had significantly lower breeding success in 2007/08 than in 2008/09 (2007/08, P<0.001, BS=0.12; 2008/09, P=0.02, BS=0.48; Tables 2.3 and 2.4). Damara Terns breeding at Elizabeth Bay had significantly higher breeding success in 2007/08 than in 2008/09 (2007/08, P=0.001, BS=0.24; 2008/09, P<0.001, BS=0.09, Table 2.4). Damara Terns breeding at Marmora Pan also had significantly higher breeding success in 2007/08 than in 2008/09 (2007/08, P<0.001, BS=0.25; 2008/09, P<0.001, BS=0.08; Tables 2.3 and 2.4).

Of all colonies in the south, the number of nests was highest at Hottentots Bay; Elizabeth Bay had the lowest number of nests (Tables 2.3 and 2.4). Hottentots Bay had fewer nests in 2007/08 than in 2008/09 (Tables 2.3 and 2.4). Grosse Bucht had more nests in 2007/08 than in 2008/09 (Tables 2.3 and 2.4). The number of nests was higher at Elizabeth Bay in 2007/08 than in 2008/09 (Tables 2.3 and 2.4). The number of nests was higher in 2007/08 than in 2008/09 at Marmora Pan (Tables 2.3 and 2.4).

Nest failures

Predation was the most common cause of known nest failure (79% of egg losses and 72% of chick losses, Table 2.5). The Black-backed Jackal was the most common predator of eggs and chicks (65% of egg losses, 33% of chick losses, Table 2.5).

The Pied Crow *Corvus albus* and Kelp Gull *Larus dominicanus* were each responsible for 2% of egg failures and 2% of chick failures (Table 2.5). Rock Kestrels *Falco rupicolus* were accountable for 5% of chick losses (Table 2.5). Other observed predators included the White-fronted Plover *Charadrius marginatus*, Namib Desert Gerbil *Gerbillurus tytonis* and Pale-chanting Goshawk *Melierax canorus* (Table 2.5). White-fronted Plovers were seen fatally attacking and injuring four Damara Tern chicks when both species were nesting in close proximity. Damara Tern parents would seldom mob these plovers while these activities occurred. Unknown predators could have included any of the above predators but evidence to determine which species was responsible per failure was not available. Unknown and other predators were responsible for 10% of egg losses and 30% of chick losses (Table 2.5).

Four percent of egg failures were due to egg infertility, and 9% of egg failures were caused by abandonment (Table 2.5). Only during extreme tides or unpredictable and sporadic rainfall, was there nest flooding. These events were rare, and were recorded only once at two sites, Hottentots Bay and Grosse Bucht (both in the south). Of 578 egg failures, 0.5% were attributed to nest site flooding (Table 2.5). Human disturbance involved off-road driving, trampling by horses and coastal development, and accounted for 4% of egg losses and 2% of chick losses (Table 2.5). Heat exposure killed 2% of the chicks that failed to survive. Six chicks died while hatching (1%, Table 2.5), and 7% of chicks died of unknown causes (Table 2.5).

In the south, predation was generally the most common cause of nest failure for all four colonies (Table 2.4). Predation was lowest at Hottentots Bay during both seasons and was highest at Marmora Pan during both seasons (Table 2.4). The rate of abandonment and/or egg infertility were the most common causes of nest failure at Hottentots Bay in 2007/08 and at Grosse Bucht in 2008/09 (Table 2.4). Jackal predation was most common at

Elizabeth Bay and Marmora Pan during both seasons (Table 2.4). No nests were observed to fail because of human disturbance in southern Namibia.

Discussion

The clutch-size in the Damara Tern is one, and thus different to all other small terns. The mean incubation period of the Damara Tern is 23 days. Damara Terns breeding in Namibia have a probability of success of 0.38, although breeding success varies significantly between colonies. Predation is the most common cause of nest failure in Namibia and Black-backed Jackals are the most common predators of tern eggs and chicks at most colonies.

Clutch-size

The small clutch-size in Damara Terns is a unique trait among the small terns (Table 1.1 in Chapter 1) and warrants discussion. Frost and Shaughnessy (1976) suggested that food delivery rate may be lower than in other in-shore terns because Damara Terns need to travel further distances to the foraging areas as a consequence of inland nesting. The ability of parents to provide food for their offspring is generally considered a major factor shaping reproductive strategies of birds with nidicolous young (Konarzewski *et al.* 1993). However, the mean feeding frequency for Damara Terns is 1.44 feeds/hour, the same as the Little Tern (Table 3.4 in Chapter 3). In addition, chicks often refuse food if offered too frequently (A. J. Williams *in litt.*, pers. obs). There have been no records of chicks dying of starvation (see also Frost and Shaughnessy 1976, Clinning 1978, Braby *et al.* 2001, A.J. Williams *in litt.*). Therefore food delivery rate is unlikely to be a limiting factor in determining clutch-size in Damara Terns.

Clinning (1978) suggested that an increase in brood size of the Damara Tern would limit both the rate of feeding and the amount of protection individual young would obtain. Although adult presence decreases as the chick gets older, Damara Tern chicks are more often accompanied by a parent than Peruvian Tern *Sterna lorata* chicks (pers. obs). Predation (by natural predators) is a high risk for eggs and chicks of Damara Terns in Namibia, possibly more so than for other small terns. In fact, predation in other small terns has only increased recently as a result of anthropogenic activities (Holloway 1993, Kirsch 1996, Brunton 1997, Zuria and Mellink 2002, C. Guerra pers. comm.). Several workers have considered nest predation to be an important force in the evolution of clutch size (Skutch 1949, Cody 1966, Lima 1987). Safriel (1975) suggested that a parent's ability to defend its brood from predators may be a strong determinant of clutch-size. Frost and Shaughnessy (1976) postulated that the one-egg clutch in the Damara Tern is an evolutionary trade-off between maximizing a rapid growth rate of chicks and high risk of predation (i.e. the faster a chick fledges, the lower the risk of predation). However, growth rates of Damara Tern chicks were found to be slower than that of other small terns (Table 3.4 in Chapter 3). In addition, chick fledging period is similar to that of the Little and Least Terns (both of which have 2–3-egg clutches, Table 1.1 in Chapter 1).

The energetic content of prey fed to Damara Tern chicks may be lower than prey fed to other small tern species (Chapter 3 and 6). It is thus possible that the one-egg clutch is not only a result of the high risk of predation, but rather a combination of low energy content of food items, and predation risk. However, further studies would be required to test this hypothesis. By rearing only one chick, Damara Tern parents can allocate more time to protecting their chick from predators. Additionally, in light of a high rate of nest predation, a small clutch size would be favoured by natural selection, because it is less energetically expensive to invest in a replacement clutch (Slagsvold 1984). There has been evidence based on recent research that in some species, like gulls, egg production is the major determinant for clutch size, because producing eggs is demanding and costly for the female (Monaghan and Nager 1997, Monaghan *et al.* 1998, Nager *et al.* 2001). In view of slow growth rates of chicks in relation to other small tern species (Chapter 3), and the possibility of low energy content of prey items compared with other small terns (Chapters 3 and 6), low food quality could also restrict egg production. A combination of the above aspects could have limited clutch size in the Damara Tern.

Breeding success and number of nests

Overall breeding success in Namibia was 15% lower than the breeding success postulated by Simmons (2005a). There was a significantly higher breeding success in the south (10% higher than central, 7% higher than north). However, these comparisons are difficult to make because each coastal area represented different years. The breeding success data from the north is now over a decade old (sporadic monitoring, 1983–1993) and jackal densities may have increased along with the northward shift in Cape Fur Seal *Arctocephalus pusillus pusillus* populations on which coastal jackals prey (Kirkman *et al.* 2007). This possible increase in jackal densities may have had a negative effect on breeding success and number of Damara Terns in northern Namibia (Chapter 9).

In central Namibia, the Horses Graves colony generally had a higher probability of breeding success than the neighbouring colony Caution Reef. Horses Graves lies further from the coast than Caution Reef and is situated in-between dunes so areas here may not have been frequented by Black-backed Jackals as often as at Caution Reef. Jackal predation of eggs was less frequent at Horses Graves than at Caution Reef. It is believed that nesting further inland is an evolutionary adaptation to avoid shoreline predators (Frost and Shaughnessy 1976, Clinning 1978, Simmons and Braine 1994).

The highest breeding success at both Horses Graves and Caution Reef was during 2001/02. During this time conservation measures had just been put in place to protect both colonies from off-road driving (Braby *et al.* 2001), although Horses Graves was not yet fenced off from the public (Chapter 8). The cause of the low probability of breeding success in 2003/04 at Horses Graves may be linked to both a higher proportion of jackal predation of eggs, and possible predations of chicks by breeding Rock Kestrels in the area, which had just arrived the season prior to this (Chapter 8). Fluctuating and low breeding success at Caution Reef was probably a result of (a) the presence of a jackal den in the vicinity, (b) fluctuating densities of Black-backed Jackals, as a result of offal from human recreation, and (c) the possibility that some jackals may have opportunistically targeted Damara Tern eggs and chicks. After jackal populations at Caution Reef were controlled (R.J. Braby unpubl. data), breeding success increased (2009/10) and predation of eggs by jackals decreased.

The number of nests at Horses Graves and Caution Reef decreased during seasons of low SOI. This infers that during Benguela Niños and warm sea surface temperatures less Damara Terns decide to breed. El Niños have been shown to impact the decision to breed in other small tern species (Massey *et al.* 1992, Zavalaga *et al.* 2008). In addition, the number of nests were probably also affected by replacement-laying after initial failures, although data for this was not directly available. Replacement clutches do occur in Damara Terns (Chapter 8, pers. obs), and are known to occur in other small tern species (Massey and Atwood 1981).

In southern Namibia, Hottentots Bay had, comparably, the largest number of nests and the best breeding success of all the southern colonies. This may be attributable to the size and substrate of the breeding area, which rendered nests both cryptic and isolated from predators (Plate 1, Chapter 7). Because it occurs in the restricted area and is virtually inaccessible, it was also protected from human disturbance (Chapter 7, Chapter 9). The smaller number of nests and breeding success at colonies in the south from 2007/08 to 2008/09 may have been a result of food limitations, such as shortages or decreases in food quality. These are known to have an effect on breeding terns (Nisbet 1978, Monaghan *et al.* 1989). The recorded number of nests at Hottentots Bay was higher in 2008/09 than in 2007/08. However, this was due to substantially increased observer effort and it is likely that the number of nests was actually larger in 2007/08. Breeding success at Grosse Bucht was better in 2008/09 than in 2007/08 possibly because there were less jackal predations.

Predation was the most frequent cause of nest loss in Damara Terns breeding in Namibia. The Black-backed Jackal was the most common predator preying on eggs and chicks of Damara Terns. This finding is not new (Frost and Shaughnessy 1976, Clinning 1978, Simmons and Braine 1994), and jackals may be linked to evolutionary adaptations of inland nesting and one-egg clutches in Damara Terns (Frost and Shaughnessy 1976, Simmons and Braine 1994). Aerial predators like the Pied Crow, Kelp Gull and Rock Kestrel may also have taken chicks. However, little evidence for this exists. These predators are mobbed frantically when they approach breeding areas (pers. obs). Therefore, they must be considered important predators of chicks and eggs of Damara Terns. White-fronted Plovers killing Damara Tern chicks has previously been documented (Simmons 2005a). Territorial aggression in plovers is common (Simmons 1953, Cairns 1982). At a young age, Damara Tern chicks and White-fronted Plover chicks look similar. It is likely that Damara Tern chicks are mistaken as White-fronted Plover chicks by White-fronted Plover adults when adults of both species nest in close proximity.

Egg abandonment and infertility may be attributed to food shortages. In addition, chicks dying while hatching may have been due to the production of low quality eggs, also as a result of food shortages or low food quality. Egg abandonment has been indirectly linked to food shortages in Least Terns (Atwood and Kelly 1984, Atwood and Massey 1988).

Damara Terns have low fecundity as a result of a small clutch and low breeding success compared with most other small terns (Table 1.1 in Chapter 1). In light of this low fecundity, special consideration should be given towards the protection and management of breeding areas in Namibia. In addition, human disturbance was low mainly because monitoring was conducted in areas which were mostly protected and/or isolated. For instance, the breeding areas north of Swakopmund, where off-road driving is not strictly regulated, human disturbance has the potential to be an important cause of nest failure. Chicks have been observed being trampled by vehicles in these areas, even on the main road between Swakopmund and Hentiesbay (which, in some areas, Damara Tern chicks have to cross to get closer to the sea, pers. obs, Figure 1.1 in Chapter 1). Important breeding areas should be allocated protection as a step towards the conservation of breeding Damara Terns (Chapter 9). These areas should be protected from human disturbance. Human disturbances should also include indirect causes of nest failures, such as increases in jackal densities as a result of human recreation (i.e. offal left behind on beaches) on beaches. Encouraging fishermen and other recreational beach-users to take their garbage and offal with them when they leave might be one way reduce the number of jackals patrolling the beach.

Table 2.1: Results of the generalized linear model for breeding success of Damara Tern nests in Namibia in relation to coastal area as explanatory variable, with "central" set as the baseline of the model. The modelled probability of breeding success (BS) was calculated using the inverse of the logistic transformation from the parameter coefficients. Standard errors are given for the coefficients (SE).

Parameter	Coefficient	SE	t_{1928}	P-value	BS
Constant	–3.739	0.050	–75.35	<0.001	–
North	–0.094	0.135	–0.69	0.49	0.37
Central	0	0	0	–	0.34
South	–0.284	0.108	–2.62	0.009	0.44

Table 2.2: Results of the generalized linear model for breeding success of Damara Tern nests at two colonies in central Namibia in relation to colony and breeding season as explanatory variables. Caution Reef in 2000/01 was set as the baseline of the model. The modelled probability of breeding success (BS) was calculated using the inverse of the logistic transformation from the parameter coefficients.

Parameter	Nest no	Coefficient	SE	$t_{1025,2}$	P-value	BS
constant		-4.193	0.499	-8.40	<0.001	
HORSES GRAVES						
2000/01	No data	No data	No data	No data	No data	No data
2001/02	59	–0.784	0.625	0.625	0.21	0.73
2002/03	122	–0.058	0.538	0.538	0.91	0.52
2003/04	89	0.839	0.525	1.60	0.11	0.21
2004/05	97	0.001	0.545	0.00	1.00	0.50
2005/06*	32	–0.400	1.12	-0.36	0.72	0.63
2006/07	69	0.036	0.547	0.07	0.94	0.49
2007/08	56	0.401	0.558	0.72	0.47	0.36
2008/09	54	0.154	0.552	0.28	0.78	0.45
2009/10	45	0.172	0.571	0.30	0.76	0.44
CAUTION REEF						
2000/01	48	0	0	0	–	0.50
2001/02	92	–0.144	0.552	–0.26	0.79	0.55
2002/03	56	0.943	0.545	1.73	0.08	0.17
2003/04	40	0.660	0.583	1.13	0.26	0.27
2004/05	60	0.277	0.562	0.49	0.62	0.40
2005/06*	13	Insuff. data	Insuff. data	Insuff. data	Insuff.	Insuff. data
2006/07	92	0.686	0.523	1.31	0.19	0.26
2007/08	52	1.232	0.531	2.32	0.02	0.10
2008/09	71	1.331	0.517	2.57	0.01	0.08
2009/10	108	0.643	0.520	1.24	0.215	0.27

* Not monitored for full season.

Table 2.3: Results of the generalized linear model for breeding success of Damara Tern nests at four colonies in southern Namibia in relation to colony and breeding season as explanatory variables. Hottentots Bay in 2007/08 was set as the baseline of the model. The modelled probability of breeding success (BS) was calculated using the inverse of the logistic transformation from the parameter coefficient.

Parameter	**Nest no**	**Coefficient**	**SE**	$t_{283,2}$	**P-value**	**BS**
constant		–5.359	0.407	–13.18	<0.001	–
HOTTENTOTS BAY						
2007/08	80	0	0	0	–	0.80
2008/09	187	0.967	0.447	2.16	0.03	0.56
GROSSE BUCHT						
2007/08	21	2.299	0.482	4.77	<0.001	0.12
2008/09	17	1.231	0.526	2.34	0.02	0.48
ELIZABETH BAY						
2007/08	13	1.895	0.539	3.52	0.001	0.24
2008/09	4	2.414	0.644	3.75	<0.001	0.09
MARMORA PAN						
2007/08	55	1.864	0.450	4.14	<0.001	0.25
2008/09	13	2.490	0.539	4.62	<0.001	0.08

Table 2.4: Determined nest outcomes (DNO) of total nests (TN) at four breeding colonies of Damara Terns in southern Namibia during two breeding seasons. DNO include only the nests for which outcomes (at egg or chick phase) were known. The success or cause of nest failure; predation, abandoned/addled, other, are given as percentages of the DNO. Predators included Black-backed Jackals, Pied Crows, Kelp Gulls and Rock Kestrels. Predation by Black-backed Jackals (BBJ predation) indicates nests predated only by Black-backed Jackals. "Other" indicates nest failures that include heat or wind exposure, unknown cause of death, flooding, and egg cracked.

Colonies	Season	DNO	TN	Success (%)	Predation (%)	BBJ predation (%)	Abandoned/addled (%)	Other (%)
Hottentots Bay	2007/08	7	80	77.4	16.1	3.2	18.2	9.1
	2008/09	103	187	72.8	18.4	9.7	5.8	2.9
Grosse Bucht	2007/08	18	21	22.2	55.6	33.3	0.0	22.2
	2008/09	17	17	47.1	23.5	17.6	23.5	11.8
Elizabeth Bay	2007/08	11	11	36.4	63.6	45.5	0.0	0.0
	2008/09	4	4	0.0	75.0	50.0	0.0	25.0
Marmora Pan	2007/08	53	55	26.4	87.3	59.0	0.0	1.9
	2008/09	10	13	10.0	80.0	40.0	0.0	10.0

Table 2.5: Causes of egg and chick failures based on nests with known outcomes of Damara Terns breeding in Namibia.

	EGG (n)	Percentage (%)	CHICK (n)	Percentage (%)
Total nest failures	578		44	
Black-backed Jackal	375	65	14	33
Pied Crow	11	2	1	2
Kelp Gull	11	2	1	2
Rock Kestrel	N/A	N/A	2	5
Other/ Unknown predator	56	10	13	30
Egg Infertile/ addle	21	4	N/A	N/A
Abandonment	53	9	N/A	N/A
Human disturbance	23	4	1	2
Nest site flooded	3	0.5	N/A	N/A
Sandstorm exposure	1	0.1	1	2
Heat exposure	0	0	1	2
Chick died hatching	6	1	N/A	N/A
Chick died of unknown cause	N/A	N/A	3	7

* Other predators include the White-fronted Plover, Namib Desert Gerbil, Pale-chanting Goshawk. Unknown predator is defined because the loss of the egg or chick could be attributed to a predator but a specific predator could not be identified as the cause.

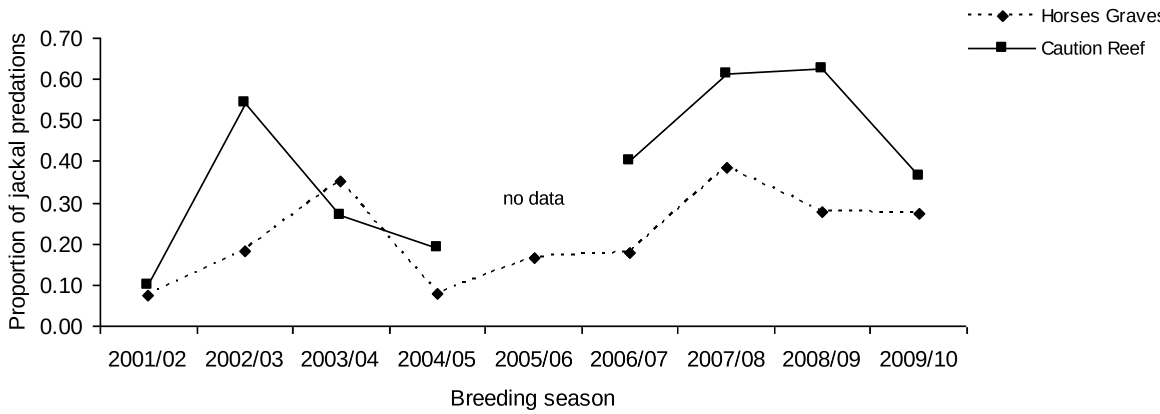


Figure 2.1: Proportion of predations on eggs attributed to Black-backed Jackals as a fraction of all known hatching outcomes (i.e. if egg hatched successfully or was predated) of Damara Tern nests at Caution Reef and Horses Graves, Swakopmund, over breeding seasons 2001/02 to 2009/10. Data were not available for 2000/01 for both colonies and 2005/06 for Caution Reef.

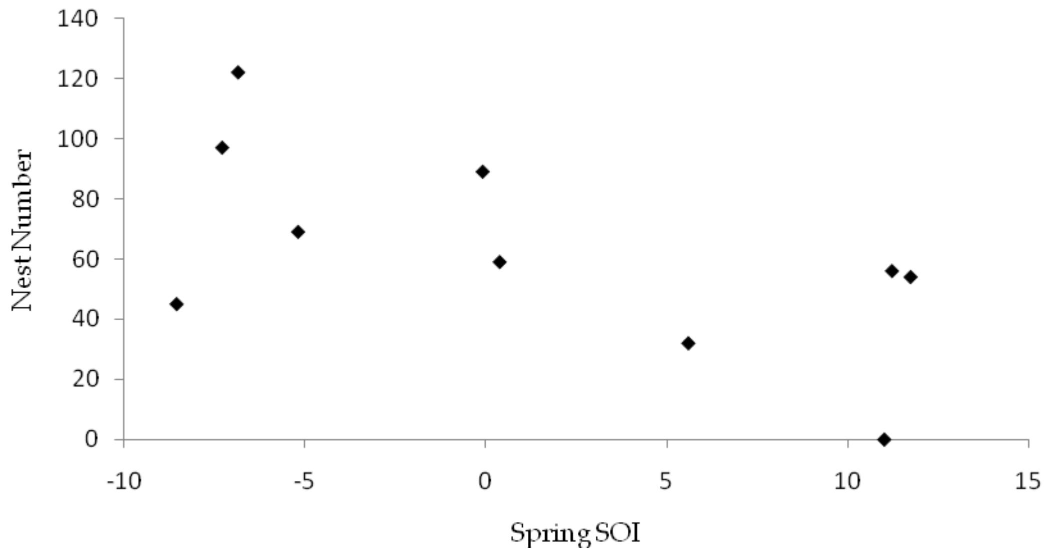


Figure 2.2: Spring Southern Oscillation Index (SOI) as compared to the number of Damara Tern nests per season (each marker represents one season) at a colony called Horses Graves in Namibia.

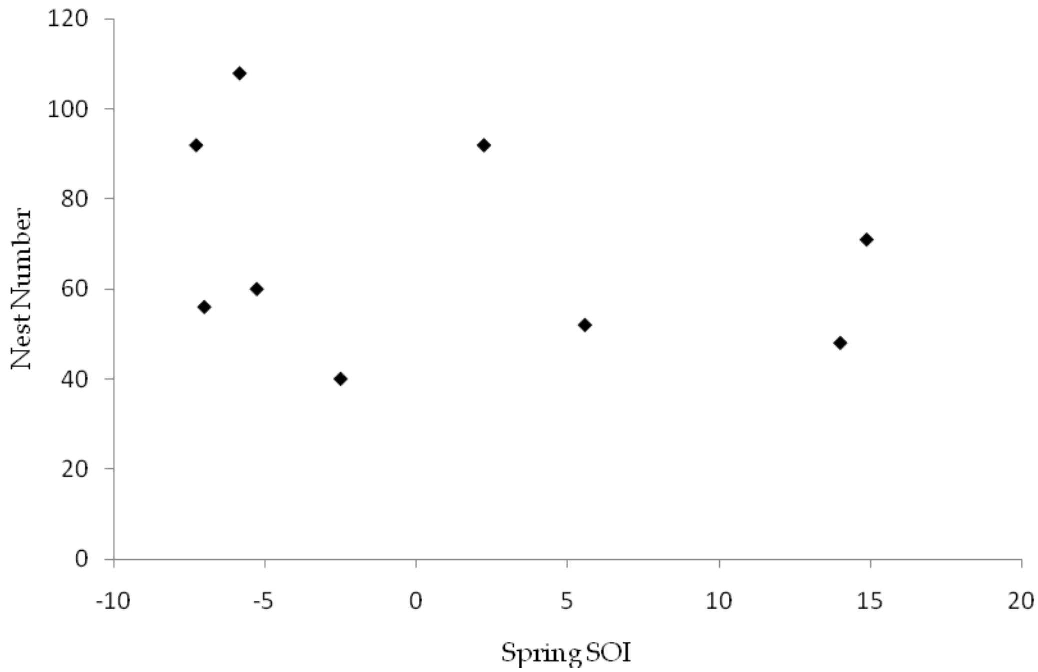


Figure 2.3: Spring Southern Oscillation Index (SOI) as compared to the number of Damara Tern nests per season (each marker represents one season) at a colony called Caution Reef in Namibia.

Chapter 3

Growth patterns, fledging period and feeding rate of Damara Tern *Sterna balaenarum* chicks in Namibia

Growth patterns, fledging period and feeding rate of Damara Tern chicks in Namibia

Introduction

Differences in chick growth patterns among species of terns have been attributed to food availability and other ecological factors (Ricklefs 1979, 1983, 1992, Ricklefs and White 1981). Le Roux (2006) considered the growth rates of different structures of the Swift Tern *Sterna bergii*, and found that the growth of certain structures was initially prioritized with regards to resource allocation and suggested that this might be due to predation risk.

Generally, slow growth rates, long fledging periods and small clutches are traits that have evolved as a result of food limitation (Ricklefs and White 1981, Hockey and Wilson 2003). However, predation risk can equally be argued as a limiting factor in the reproductive traits of seabirds (Cody 1966, Slagsvold 1984, Lima 1987).

Like in many seabirds, Damara Tern chicks are semi-precocial. Chicks leave the nest only two days after hatching and are highly mobile, moving large distances from one day to the next (Simmons and Braine 1994). They rely on parental feeding until at least two and a half months after fledging (Clinning 1978). Fledging periods of Damara Terns are similar to other small terns (Table 1.1 in Chapter 1). They breed in the desert environment of the Namibian coastline, where strong upwellings in the Benguela Current presents high productivity (Cushing 1971). Damara Terns generally breed far inland to avoid high predation rates (Frost and Shaughnessy 1976, Clinning 1978), and thus have to travel a relatively large distance between their breeding and foraging grounds. However, they rear only one chick and chicks often refuse food from parents (pers. obs, T. Tree pers. comm., A.J. Williams *in litt.*). Feeding rates are considered to be relatively high (A.J. Williams *in litt.*).

Little is known of the growth and development of Damara Tern chicks. This chapter aims to estimate growth rates and fledging periods of Damara Terns, and investigate le Roux's hypothesis of prioritizing growth structures according to ecological factors in Damara Tern chicks. The chapter also describes the feeding frequency of Damara Tern chicks.

Study Area and methods

Chick growth rate and fledging period

Growth rates and fledging period data were collected from 11 breeding localities along the Namibian coastline (Figures 1.2–1.4 in Chapter 1):
(a) from November 1992–February 1993: Möwe Bay Airstrip (19°22′S, 12°43′E), Huab (S20°50 E13°26) and Ogden Rocks (S24°22 E24°42);
(b) during January 2006: Möwe Bay Airstrip;
(c) from 15 January–31 March 2007, 22 September 2007–31 March 2008 and 1 October 2008–31 March 2009: Hottentots Bay (26°14′S, 14°59′E), Grosse Bucht (26°43′S, 15°40′E), Elizabeth Bay (26°55′S, 15°14′E) and Marmora Pan (27°45′S, 15°34′E);
(d) from November 2009–March 2010: Durissa Bay Pans (21°15′S, 13°41′E), White Stones (21°39′S, 13°56′E), Horses Graves (S22°42 E14°33) and Caution Reef (S22°44 E14°32).

Shortly after hatching, or when found for the first time, each chick was ringed with a SAFRING stainless steel ring (2.8 mm internal diameter, and colour rings were placed on the left leg). Chicks were weighed to the nearest 1 g using a Pesola spring balance. Structural growth measurements were taken using digital calipers and included head (and bill) length, wing length, bill length, and foot length (tarsus and toe). Wing length was measured in terms of maximum length from the curvature of the carpal joint to the end of the (down/quill) feather. Relocated chicks were measured at 2–7 day intervals. Because the growth patterns of most measurements did not conform to the standard growth curves, such as logistic or Gompertz (Reiss 1989), a descriptive statistical approach that was devised for Swift Terns in South Africa (le Roux 2006) was used. See Annex 2 for the statistical methodology as described by le Roux (2006). Fledging periods were determined from chicks for which known hatching and first flight dates were known.

Feeding rate

I observed Damara Tern chicks between hatching and just after fledging over the daylight period (06h00–20h00) during the breeding seasons October 2008–March 2009 and October 2009–March 2010 at six breeding colonies along the Namibian coastline: Durissa Bay Pans, White Stones, Horses Graves, Caution Reef, Hottentots Bay, Grosse Bucht and Elizabeth Bay (Figures 1.2 and 1.3 in Chapter 1). During continuous observations I recorded the number of times a chick was fed by its parents. Observations were either made from a car or by lying still flat on the ground and observing by binoculars (8×42) or telescope from a distance of *c.* 150 m. To avoid disturbance and thus bias results due to observer presence, chicks spotted from afar were not measured prior to starting observations. Adults would usually mob during occasions when I did measure chicks. On these occasions I only started recording my observation once observer presence was ignored, *c.* 20 mins. Simultaneous observations never exceeded two chicks, and most observations were on single chicks at any given time.

The standard observation period was 120 minutes, but some periods were shorter. I tested whether feeding rate increased with age by using a generalized linear model with a Poisson distribution and logarithmic link function to model the number of feeds per hour, using observation time as the offset variable (McCullagh and Nelder 1989).

Results

Chick growth rate and fledging period

In total, there were 282 recaptures of 220 chicks ringed. Chicks found on the day (day=0) they hatched were defined as hatchlings. The mean mass of hatchlings was 7.05 g (SD=0.92 g, Table 3.1). The mass of hatchlings had a coefficient variation (CV) of 13.09%. Foot length (CV=4.44%) and head length (CV=5.06%) showed least variability of the structures measured (Table 3.1). Because I had no measurement data for birds that had fledged (i.e. taken first flight, chicks that were 21 days (minimum age at fledging, this chapter) and older were defined as fledglings and their measurements were used (Table 3.2). This approach suggested that the mean fledging mass was 43.5 g (SD=2.7 g) and the mean fledging wing length was 100.8 mm (SD=3.6 mm).

Measurements obtained from 401 adult Damara Terns (R.J. Braby unpubl. data) indicated that the fledgling wing length was *c.* 60% of the wing length of breeding adults (Tables 3.2 and 3.3). Fledging mass was *c.* 85% of adult mass (Tables 3.2 and 3.3). The head length of the fledglings was 72% of adult head length, but the bill length was only 58% of adult bill length (Tables 3.2 and 3.3). Foot length of adults and fledglings was similar (Tables 3.2 and 3.3).

The growth rates from hatching to fledging ranged between 1 and 2.6 g/day and peaked when chicks were between 19 and 23 g at a mean of 2.58 g/day (*c.* 7–8 days old, Figure 3.1A). At fledging mass, the mean growth rate was 1.25 g/day (Figure 3.1A). The rate of growth in mass showed large scatter (Figure 3.1B). The coefficient of variation for the peak growth rate was 36.4%. The transformation of the growth rate curve into the plot showing average mass in relation to age indicated nearly linear growth in mass from *c.* 5–15 days and then a lower rate of linear growth from *c.* 17–25 days (Figure 3.1B). The mean growth rate of mass between hatching and fledging was 1.99 g/day.

The growth rate of the wing length showed a relatively steady increase from 1 mm/day at hatching to 3 mm/day when the wing length was 24 mm, after which there was a more rapid increase from 3.5 mm/day to a peak of 5.85 mm/day at wing length 93 mm (*c.* 22 days, Figure 3.2A). Thereafter the rate decreased very slightly towards fledging (5.72 mm/day, as the chick reached *c.* 23 days, Figure 3.2A). The growth curve for wing length against age reflected this pattern (Figure 3.2B). The wing length increased slowly until an age of *c.* 15 days, and then showed an almost linear increase towards fledging (the very slight decrease towards fledging was not visible in the growth curve, Figure 3.2B). At 15 days, the wing length was 49.13 mm, 28% of adult size. The rate of growth for wing length showed less scatter than that for mass (Figure 3.1A and 3.2A). At the point when wing length was increasing most rapidly (5.85 mm/day, SD=1.24 mm/day) the coefficient of variation was 21.21%. If the growth rate stayed relatively constant, about two more weeks would be needed for fledglings to reach adult wing length.

The growth rate of head length had its largest value, 2.68 mm/day, at hatching when the mean head length was 22.62 mm. After hatching, it decreased steadily until the head length reached 26.00 mm (2.01 mm/day, Figure 3.3A). The growth rate then showed a steady rate of decrease until it reached 0.66 mm/day at fledging, when the head length was 47.37 mm, at a mean rate 1.08 mm/day. The growth curve for head length reflected this pattern (Figure 3.3B). The head length increased rapidly until *c.* 5 days, and then showed an almost linear increase to fledging. The rate of growth for head length showed relatively large scatter (Figure 3.3A). At hatching, when head length was increasing most rapidly (2.68 mm/day), the standard deviation of the rate of increase was 1.23 mm/day. The coefficient of variation of this was 45.8%, almost 10% higher than the coefficient of variation for peak mass growth rate.

The growth rates of bill length increased from about 0.31 mm/day (at 6.6 mm), to about 0.65 mm/day (at 17.5 mm, Figure 3.4A). Thereafter the growth rates decreased to fledging where it was 0.38 mm/day (at 18.95 mm, Figure 3.4A). This was reflected in the growth curve (Figure 3.4B), where there was linear growth up until fledging and then began to level. The growth rate plot showed large scatter (Figure 3.4A). At the peak growth rate of a mean of 0.65 mm/day at 17.5 mm, the coefficient of variation of was 49.4%.

The growth rates of foot length showed a rapid increase in growth at hatching (17.46 mm, 2.15 mm/day), and then the growth rate decreased steadily until fledging (29.4 mm, 0.12 mm/day, Figure 3.5A). This is shown in the growth curve (Figure 3.5B), where growth rate was rapid until *c.* 7 days, and slowed down to almost no growth towards fledging. The growth rate plot shows large scatter (Figure 3.5A). At peak growth rate (*c.* hatching, 17.46 mm), with a mean growth rate of 2.15 mm/day, the coefficient of variation was 46.0%.
The mean fledging period for 10 Damara Tern chicks was 22.5 days (SD=0.85, range= 21–24 days).

Feeding rate

Of 34 observation bouts (30 minutes–120 minutes per bout, of chicks aged between 0 days and 22 days) of chicks being fed, the mean feeding rate was 1.44 feeds/hour (SD=0.98, range= 0–4.5 feeds/hour).

The generalized linear model used to estimate feeding rates in relation to age showed that feeding rate increased significantly with age. The regression coefficient of the term relating to age was 0.043 (SE=0.018, t=2.35, P=0.019, one-sided test, Figure 3.6). The full model was

$$log_e(feeding\ rate) = -4.281 + 0.0660 \times a + log_e(t),$$

where a is age of chick (days) and t, the offset variable, is the observation period in minutes. Setting t=60, gives feeding rates per hour. The modelled feeding rate for a chick aged 0 days was 0.83 feeds/hour, increasing to 2.13 feeds/hour for a chick aged 22 days (Figure 3.6).

Discussion

This study presents the first comprehensive growth rates of Damara Tern chicks in Namibia. I also update mass and structural measurements, fledging period and feeding frequencies using larger sample sizes than have previously been available. Chicks are particularly difficult to locate because Damara Terns have small colony sizes and scattered nest distribution. In addition, chicks are camouflaged and almost always on the move. This is probably the reason why there are no earlier studies of the growth of this species, apart from Clinning (1978), who presented chick growth rates of mass, bill and wing length based on averages of one to five chicks (sample size differed between structures) of known ages. Even though I was only able to measure 220 chicks (282 recaptures) during 19 months of monitoring at 11 Damara Tern colonies, this represents by far the largest available sample of data upon which to undertake an analysis of growth for this species. In the comprehensive reviews of growth rates of terns undertaken by le Roux (2006) and Tjørve (2007), no meaningful data were available for any of the small terns.

The mean mass of hatchlings was 0.55 g larger than previously recorded (Appendix 1). The mean fledging period of 23 (rounded from 22.5) days was slightly longer than postulated by Clinning (1978). The mean mass of 43.5 g for fledglings was 3.5 g larger than previously recorded (Appendix 1). The mean mass of fledglings was 85% of the mean mass of adult terns. The mean fledging wing length was only 60% of adult wind length. Head length was 72% and bill length only 58% of adult structures. Foot length at fledging was similar to that of adults. In fact, adult foot length was reached at *c.* 12 days of age. At the same age, wing length was only 20% of adult wing length.

For the Damara Tern, resources are clearly channeled into leg growth in the first stages of development. This is appropriate because chicks are required to be mobile within days of hatching and move considerable distances to avoid predators (Clinning 1978, Simmons and Braine 1994). Although the attainment of flight is critical to the chick's survival, it seems that the development of wing length is postponed until legs are well-developed. As the chick nears fledging age the development of wings and the associated ability to fly received a greater allocation of resources. The main advantage that flight provides is the escape from predators such as the Black-backed Jackal *Canis mesomelas*. Furthermore, parents can more rapidly move their flighted chicks closer to the sea and to localities where food is abundant, and thus feed them more efficiently. This has energetic advantages for both the parents and the chick (le Roux 2006).

The Damara Tern feeds mainly by plunge-diving for prey (Simmons and Braine 1994, Chapter 6). The bill is therefore a critical component for prey capture success (le Roux 2006). However, bill development lags behind that of the other structures. Damara Terns, when they fledge, are unlikely able to feed efficiently for themselves. Extended post-fledging dependency enables chicks to be fed by their parents during the time required for their bill to reach adult length.

The order of development of leg, wing and bill seems logical, and the same was found for Swift Tern chicks in South Africa (le Roux 2006). There have been no comparative studies on other small terns. Leg development is the first priority so that chicks can be mobile to avoid predators. Wing development is the next priority, so that chicks are able to move closer to food resources and better evade predators. Because parents care for their offspring at least 2.5 months after fledging (Clinning 1978), the bill can continue growing after the other growth structures are completed.

The growth rate curve plots provide a visual impression of variability of growth of the four structures measured and of mass (Figures 3.1A–3.5A). It is useful to compare the overall impressions of variability of growth in mass and the structures (Figures 3.1A–3.5A). The relative scatter was largest for foot length and least for wing length. This impression was captured by considering the coefficient of variation of growth when the growth rate was at its largest. The coefficient of variation, the ratio of the standard deviation and the mean, quantifies the concept (le Roux 2006). The coefficient of variation of growth mass was 36.4%, wing length was 21.21%. The coefficients of variation of growth of head, bill and foot length were 45.8%, 49.4% and 46% respectively. I expected mass would have had the highest coefficient of variation, mainly because mass should fluctuate more widely than structural measures (le Roux 2006). Observed mass depends on the weighing time in relation to when the chick was last fed. It is therefore unexpected that the coefficients of variation for growth of head, bill and foot length were higher than that for mass. The reason for this may be due to the difficulty of measuring the structures precisely, and that the element of observer bias existed due to different observers measuring in the field.

The mean growth rate of mass from hatching to fledging in Damara Tern chicks was lower than that of other small tern species (Table 3.4). Damara Tern chicks are highly mobile and are rarely found in the same area from one day to the next (Simmons and Braine 1994, pers. obs). This extreme mobility has not been recorded in other tern chicks. Peruvian Tern *Sterna lorata* chicks were found to be less active than Damara Tern chicks (pers. obs). It is likely that more resources are allocated to the needs of activity than the needs of growth. Alternatively, the slower growth rate of mass of Damara Tern chicks may be a result of food availability or lower energy content of food. However, feeding rates of Damara Terns are comparable to that of other small terns (Table 3.4). In addition, Damara Tern chicks often refuse food (A.J. Williams *in litt.*, pers. obs). Food availability is therefore an unlikely limiting factor in the growth of Damara Tern chicks. The energy content of prey delivered to Damara Tern chicks may be lower than that delivered to other small tern chicks. Mugilidae species fed to Damara Tern chicks in southern Namibia had low energy content (14.88 kJ/g dry mass, Chapter 6) compared to Mugilidae species fed to Little Tern *Sterna albifrons* chicks in Portugal (20.35 kJ/g dry mass, Paiva *et al.* 2006a). Further studies should investigate the comparative energy content of similar prey species of small terns to ascertain whether energy content may be a limiting factor in Damara Tern chick growth.

The feeding rate of chicks was 61% higher than previously recorded in Namibia (Reiss and Kruger 1998). This higher result is likely to be due to a substantially larger sample size (their study had eight hours of observations). A study of feeding rates of Little Tern chicks in Portugal was found to be the same as Damara Terns (Table 3.4). Feeding rates were found to significantly increase with age. This increase may be a result of higher energy requirements of chicks as they become more active with age (pers. obs). There was insufficient data to correlate feeding rates with growth rates of Damara Tern chicks.

To ascertain why growth rates of Damara Tern chicks are slower than that of other small tern species, future studies should investigate comparative energy budget allocations, and compare energy content of food delivered to these species' chicks.

Table 3.1: Summary statistics of masses (g) and measurements (mm) of Damara Tern hatchlings in Namibia.

	Sample Size	Mean	SD	Min	Median	Max
Mass	118	7.05	0.92	4.80	7.00	9.00
Head	32	24.75	1.25	22.62	24.68	27.60
Bill	26	7.58	0.45	6.60	7.59	8.68
Wing	37	11.89	1.91	6.97	11.43	17.46
Foot	30	20.28	0.90	18.50	20.38	22.39

Table 3.2: Summary statistics of masses (g) and measurements (mm) of Damara Tern fledglings in Namibia.

	Sample Size	Mean	SD	Min	Median	Max
Mass	10	43.50	2.72	40.00	42.50	47.00
Head	3	45.01	0.99	44.34	44.54	46.14
Bill	4	17.90	1.41	15.80	18.50	18.80
Wing	5	100.82	3.57	97.00	101.00	106.00
Foot	3	28.78	0.18	28.61	28.77	28.97

Table 3.3: Summary statistics of masses (g) and measurements (mm) of breeding adult Damara Terns in Namibia.

	Sample Size	Mean	SD	Min	Median	Max
Mass	397	50.99	3.30	42.00	50.00	63.00
Head	297	62.27	2.49	48.00	62.00	72.00
Bill	349	30.10	2.34	25.50	30.10	37.00
Wing	401	172.21	4.68	152.59	172.00	175.00
Foot	10	28.25	0.98	26.78	28.25	30.52

Table 3.4: Mean growth rates of mass from hatching to fledging (g/day), and feeding rate (feeds/hr/chick) for chicks of four species of small tern.

	Mean growth rate	Feeding rate	Source
Damara Tern *S. balaenarum*	1.99	1.44	This study
Peruvian Tern *S. lorata*	2.27	–	Zavalaga *et al.* 2008
Little Tern *S. albifrons*	2.28–2.53	1.44	Paiva *et al.* 2006a
Least Tern *S. antillarum*	2.4	–	Massey 1974
	2.3		Whittier and Leslie 2005

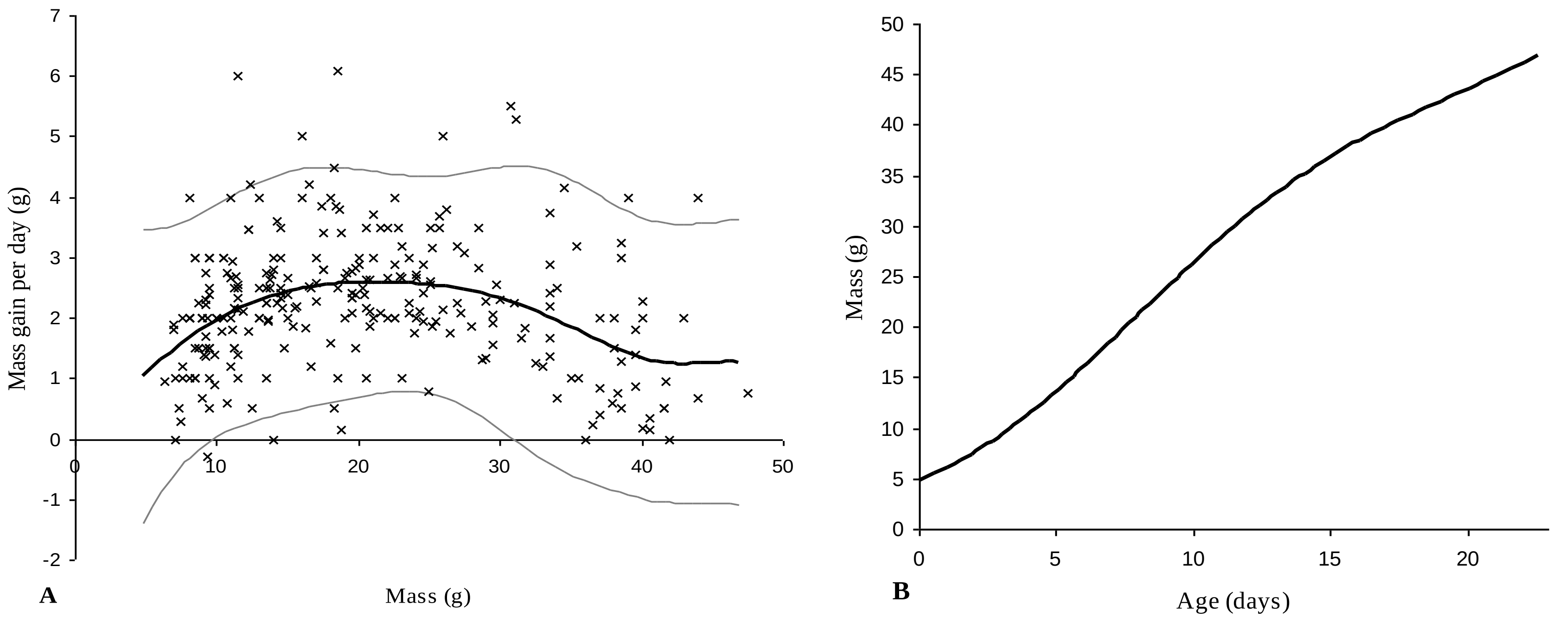


Figure 3.1: A: Growth rates (g/day) of mass of Damara Tern chicks in Namibia. Smoothed curve gives the trajectory of the mean, and upper and lower 95% confidence intervals are shown (see text). **B:** Growth curve of mass (g) of Damara Tern chicks in relation to age in days, transformed from the trajectory of the mean in A.

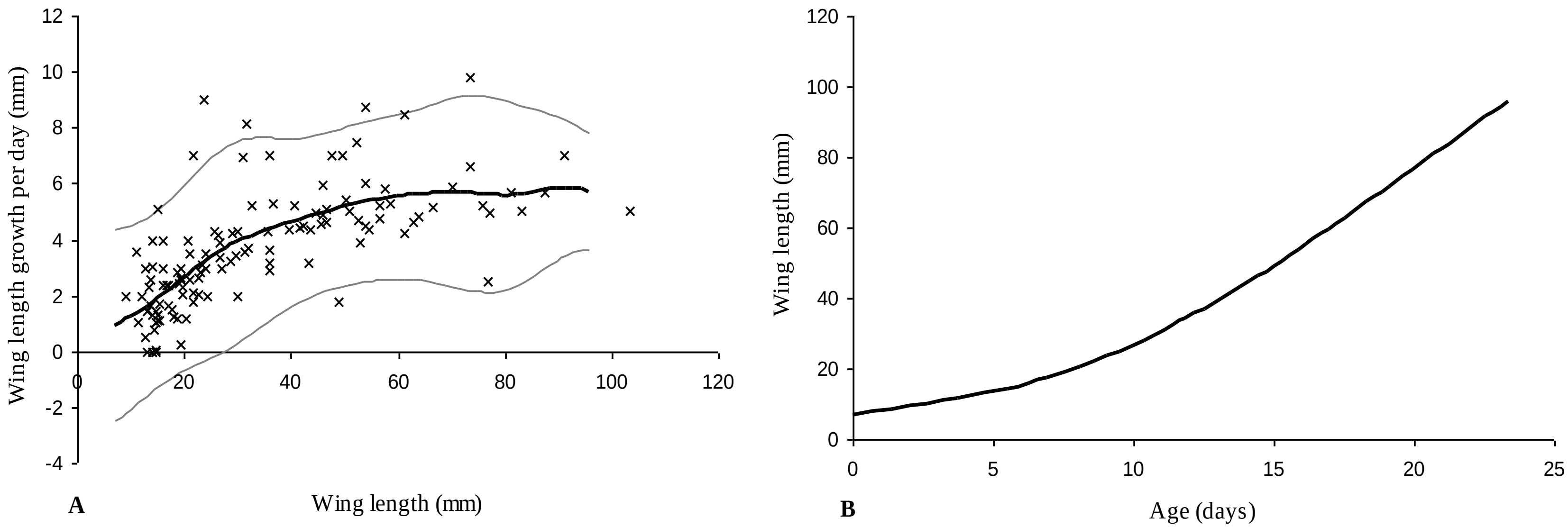


Figure 3.2: A: Growth rates (mm/day) of the wing length of Damara Tern chicks in Namibia. Smoothed curve gives the trajectory of the mean, and upper and lower 95% confidence intervals are shown (see text). **B:** Growth curve of wing length (mm) in relation to age in days, transformed from the trajectory of the mean in A.

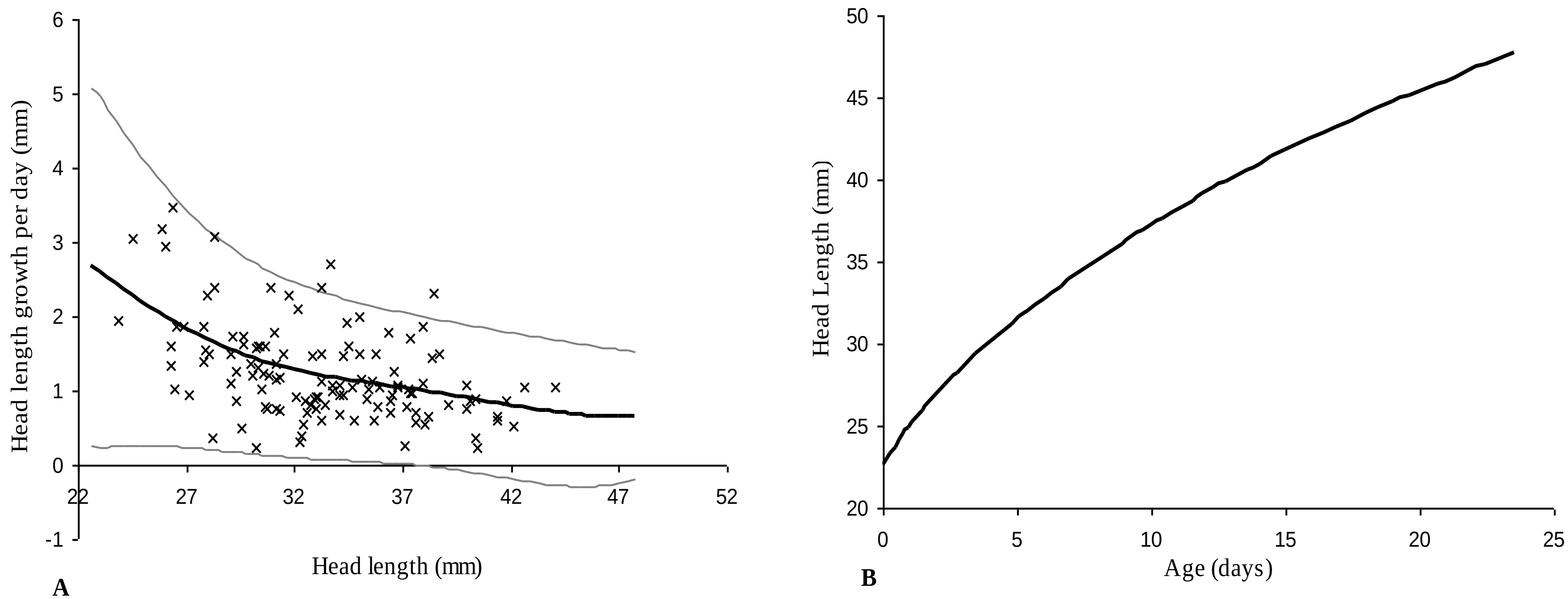


Figure 3.3: A: Growth rates (mm/day) of the head length of Damara Tern chicks in Namibia. Smoothed curve gives the trajectory of the mean, and upper and lower 95% confidence intervals are shown (see text). **B:** Growth curve of head length (mm) in relation to age in days, transformed from the trajectory of the mean in A.

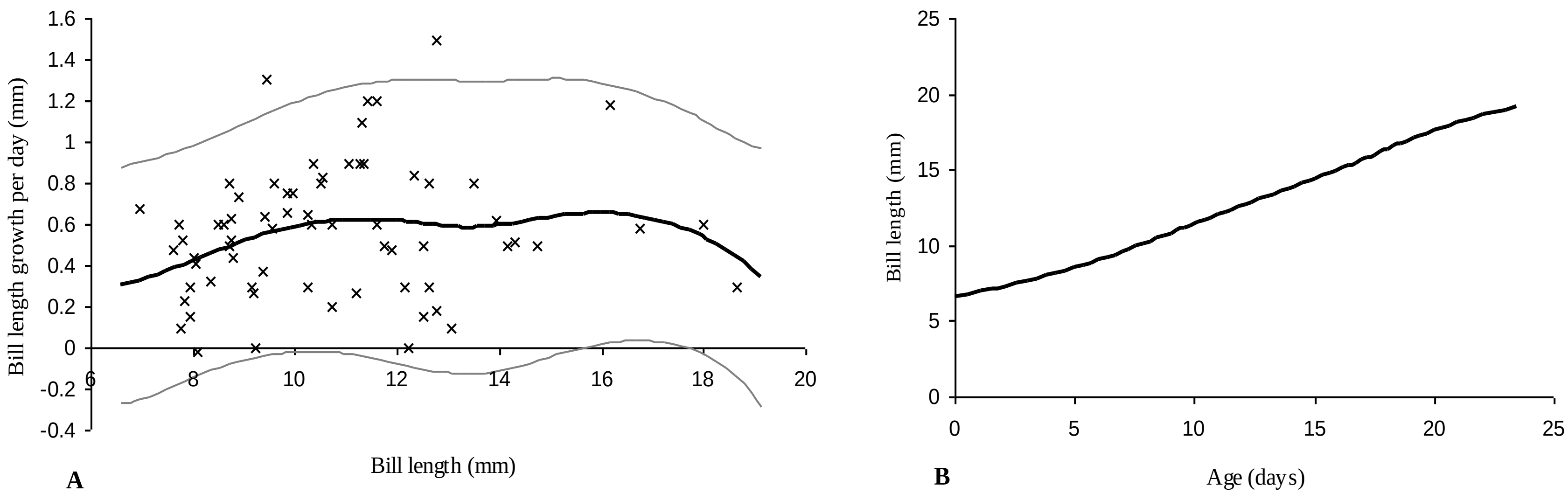


Figure 3.4: A: Growth rates (mm/day) of the bill length of Damara Tern chicks in Namibia. Smoothed curve gives the trajectory of the mean, and upper and lower 95% confidence intervals are shown (see text). **B:** Growth curve of bill length (mm) of Damara Tern chicks in relation to age in days, transformed from the trajectory of the mean in A.

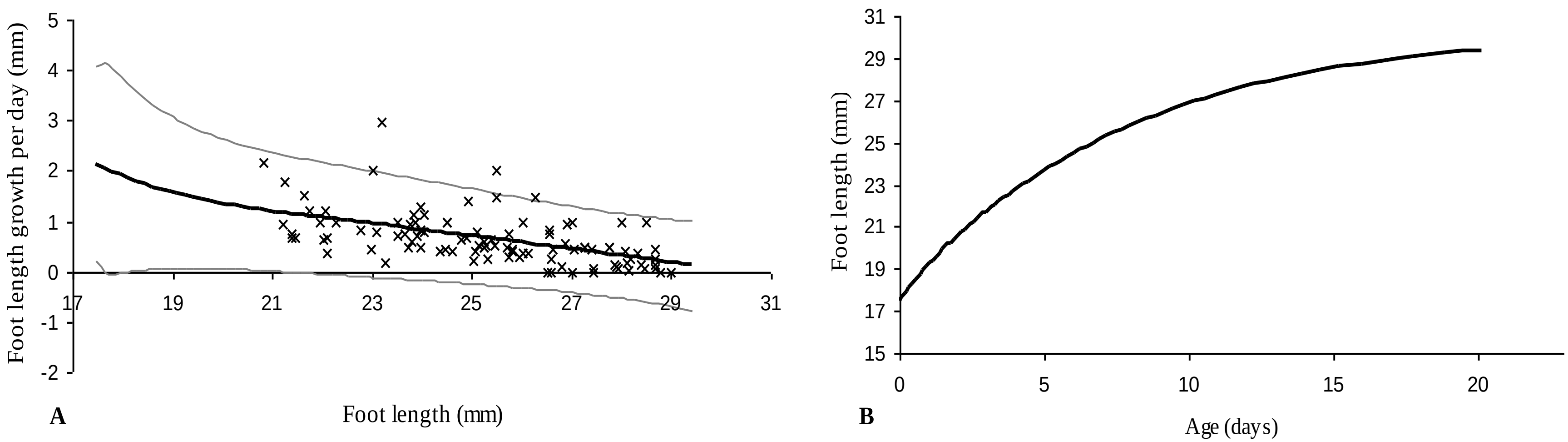


Figure 3.5: A: Growth rates (mm/day) of the foot length of Damara Tern chicks in Namibia. Smoothed curve gives the trajectory of the mean, and upper and lower 95% confidence intervals are shown (see text). **B:** Growth curve of foot length (mm) of Damara Tern chicks in relation to age in days, transformed from the trajectory of the mean in A.

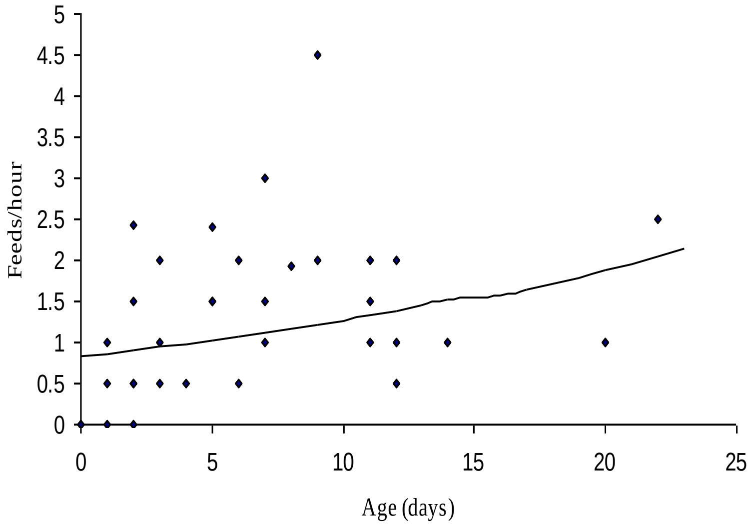


Figure 3.6: The feeding rate (feeds/hour) of Damara Tern chicks in Namibia in relation to age (days). The smoothed curve illustrates the modelled feeding rate (feeds/hour) using a generalized linear model (see text).

Chapter 4

Immature survival and age at first breeding of Damara Terns *Sterna balaenarum*: conservation from a non-breeding perspective

Immature survival and age at first breeding of Damara Terns: conservation from a non-breeding perspective

Introduction

To assess and ensure the long-term viability of any population requires an understanding of its life-history. Immature survival and the age at which a bird first breeds are important parameters in the life-history of seabirds (Lack 1967, Burger and Gochfeld 1986, Sandvik *et al.* 2008). However, long-term studies are required to attain these parameters. Such studies of seabirds are rare (Breton *et al.* 2006), and in small seabirds such as terns there are often methodological and logistic problems in studying their population ecology (Becker and Wendeln 1997). Because many seabirds migrate to isolated or inaccessible areas during non-breeding seasons, taking their fledged offspring with them, there are often periods of unobservability following fledging. Thus few studies have reported reliable estimates of survival rates for immatures (Ezard *et al.* 2006, Sandvik *et al.* 2008).

Age of first breeding, on the other hand, has been reported for several species of terns (reviewed by Mundkur 1992, Becker and Wendeln 1997, Becker *et al.* 2001). Age at first breeding may be influenced by a number of factors, such as physiological maturity, non-breeding migration, learning of food availability and predation risks at breeding grounds and acquiring skills sufficient to feed offspring (Harrington 1974, Chabrzyk and Coulson 1976, Wooller and Coulson 1977, Danchin *et al.* 1991, Mundkur 1992, Ludwigs and Becker 2002). With the exception of river terns (e.g. Indian River Tern *Sterna aurantia*), which tend not to migrate and generally have permanent and reliable access to food resources (Mundkur 1992), terns exhibit delayed or deferred maturity and initiate breeding at the age of two to three years (Mundkur 1992), and up to five years for some species (Harrington 1974). Other long-lived seabird species do not breed until seven years of age (Lack 1968, Cramp 1985).

Damara Terns breed along the desert mainland of southern Africa during the austral summer and migrate to West Africa for the non-breeding season (Simmons 2005a). Successful breeding attempts result in one fledged chick per pair and fledging dependency extends for up to two and a half months (Williams and Meyer 1986). Damara Terns breed in harsh desert environments with high risks of predation and the probability of a breeding attempt being successful is less than 40% (Chapter 2). Like most terns, Damara Terns feed by plunge-diving for prey; this skill requires considerable time to perfect and explains the extended post-fledging dependency (Ashmole and Tovar 1968, Ashmole 1971, Feare 1975, Burger 1980, Cramp 1985,).

In the light of these factors I predict that Damara Terns share the life-history traits of most terns by displaying delayed (or deferred) maturity and thus relatively high immature survival. Breeding Damara Terns are threatened by habitat loss due to coastal development (R.J. Braby unpubl. data) and disturbance caused by off-road driving (Braby *et al.* 2001, Williams *et al.* 2004, Chapter 8). In addition, non-breeding and immature Damara Terns are trapped for food in their non-breeding grounds (Braby 2010, Annex 1). However, the actual number of individuals which are killed, and the impact of this mortality on the global population, is unknown (Braby 2010). It is thus important to investigate life-history parameters that deal with life-stages outside of the breeding season to find a holistic approach to the conservation of the species, both in breeding areas, and in non-breeding areas.

The objectives of this study are two-fold: to report the first information of (a) estimates of immature survival and (2) age at first breeding of Damara Terns. The study is based on 10 years of capture-mark-recapture data at two breeding colonies on the coastline of central Namibia.

Study area

This study took place at Horses Graves (22° 42'S, 14° 33'E), 4 km south of Swakopmund, and at Caution Reef (22°44S, 14°32E), 8 km south of Swakopmund (Figure 4.1). The habitat at Caution Reef consists mainly of open and sparsely vegetated sandy plains with a raised gravel ridge through the centre (Braby *et al.* 2001), and the area comprised approximately 2.5 km^2. Horses Graves consists of a series of barchan, linear, and crescent dunes separated by gravel plains in which the terns breed (Braby *et al.* 2001), and the area comprised approximately 3.5 km^2. A more detailed description of the study area is given in Chapter 1.

Methods

Incubating adults were trapped on their nests using a netted snap-trap controlled by remote trigger from a distance of up to 200 m. Adults and chicks were trapped during the breeding seasons (October–February) from 2000/01 to 2009/10. Chicks were ringed when first found with a 2.8 mm SAFRING stainless steel rings on the right leg, and a breeding season specific colour ring on the left leg. Adults received the same combination along with an additional colour ring on the left leg specific to breeding site.

Multi-state capture-mark-recapture models were used to estimate the age at first breeding (Colbert *et al.* 1994, Lebreton *et al.* 2003). For this analysis, data on Damara Terns ringed either as nestlings (678 individuals) or adults (214 individuals) were used. The data on adult terns were included to estimate breeder recapture probabilities. Two states were defined, immature and breeder. All birds ringed as nestlings were initially assigned to the immature state. The age-specific movement probability from the immature state to the breeder state was then used as an estimate of the probabilities of first breeding at a given age. In this analysis, the maximum age at which all individuals start to breed needs to be assumed (Lebreton *et al.* 2003). Values were explored for this parameter up to a maximum of six years.

Only breeding birds were trapped, and the recapture probability in the immature stage was therefore set to zero. As a result, yearly age-specific survival was not estimated for immature birds, but an average estimate of annual survival during that life stage was obtained.

An added complication was that nestlings were ringed at variable ages, ranging from the day of hatching until shortly before fledging. The immature survival rate thus contained a component of pre-fledging mortality. To account for the resulting heterogeneity, the age when a nestling was last seen (ranging from 0.5 to 23 days) was used as an individual covariate in the analysis. This estimate of juvenile survival corresponds to an individual with mean age when last seen in the nest; this was 4.7 days. I included nestling age as a linear covariate into the models, mainly to account for heterogeneity in observed survival caused by variable age at ringing. However, I used this relationship to also estimate expected survival for individuals that reach fledging age (23 days).

In this analysis, models in which the recapture probability of breeders was constant, year-dependent, or a linear function of effort (number of hours spent trapping) were considered. Breeder survival was kept constant and a common value for both colonies was assumed.

The fit of the most general model without individual covariates (with year specific recapture probabilities) using the median-$\hat{c}$ procedure in program MARK (White and Burnham 1999) was examined. This test showed little sign of overdispersion ($\hat{c}$=1.23, se=0.02), and including the individual covariate should account for some remaining heterogeneity.

The standard optimization routine used in program MARK, based on a Newton-Raphson algorithm, did not always appear to converge properly. Therefore most models were run using the alternative optimization based on simulated annealing, also provided in program MARK. All models were run in program MARK 6.0 (White and Burnham 1999), and the sample-size adjusted Akaike's information criterion for model selection was used.

Results

Model selection favoured a model which assumed that the maximum age at first breeding was four years (Model 1, Table 4.1), that immature survival was positively related to the age when a nestling was last seen in the nest, and that the recapture rate was positively related to field effort. This model suggested that the probability of starting to breed was zero for 1-year old birds, 0.06 (95% confidence interval (CI) =0.007–0.36) for 2-year old birds, 0.26 (CI=0.03–0.78) for 3-year old birds, and made the assumption that all birds breed at 4-years old. Data sparseness could have partly affected this result, and I interpret it as showing that most Damara Terns started breeding at either 3 or 4 years of age, with an estimated 94% (26% and 68% respectively) commencing breeding at these ages.

Average annual survival of immature terns was 0.59 (CI=0.48–0.68), and adult survival was 0.87 (CI=0.73–0.94). My estimate of immature survival contains an element of pre-fledging mortality because it is mean annual survival from mean ringing age (nestlings 4.7 days old) to breeding age. I included nestling age as a linear covariate into the models, mainly to account for heterogeneity in observed survival caused by variable age at ringing. However, this relationship can be used to estimate expected survival for individuals that reach fledging age (23 days). Based on that relationship the best estimate for annual immature survival would be 0.84 (0.64–0.94), much closer to adult survival.

The youngest record of breeding was 2 years and the oldest was 15 years. The 15-year old bird was ringed as a chick at Caution Reef in November 1993, and trapped as a breeder on its nest at Caution Reef in December 2004, and again on its nest at Caution Reef in November 2008.

Discussion

My results show that, as with many seabirds, Damara Terns display high immature survival and delayed maturity. These are the first estimates of immature survival and age at first breeding for this species.

The estimated immature annual survival rate of 0.59 was lower than the adult survival rate of 0.87. However, it was higher than those of other tern species (0.27 for immature Common Terns *Sterna hirundo*, Becker *et al.* 2001; between 0.16–0.30 for immature Roseate Terns *Sterna dougallii*, Spendelow 1991, Spendelow *et al.* 2002). My estimate of immature survival contained an element of pre-fledging mortality because it is the mean annual survival from mean ringing age (4.7 days old nestling) to breeding. The calculation required for the immature survival of 0.84 relied on the assumption that survival during the nestling stage is constant, due to the linear relationship used. However, nestling survival probably improves with nestling age. I had few individuals ringed close to fledging age. Therefore, this estimate of immature survival is likely to be too high because I was attributing some immature mortality to the nestling stage. Nevertheless, it may be a realistic upper bound. In a study of Atlantic Puffins *Fratercula arctica*, where only juveniles that had fledged were considered, survival rates of immatures were not depressed in relation to adults (Sandvik *et al.* 2008). I predict that my estimate of 0.59 would have been higher if only immatures that had fledged were considered, especially when taking into account the high risk of predation during pre-fledging.

Of the six small terns closely related to the Damara Tern (Chapter 1), the only other species for which age at first breeding is known is the California Least Tern *Sterna antillarum browni*, which breeds at age three years, and rarely at age two years (Massey and Atwood 1981). The age at first breeding of three to four years of Damara Terns is similar. It is also typical of most plunge-diving terns where an extended period is needed to learn this skill, and immatures are much less efficient at foraging than adults (Dunn 1972, Ainley *et al.* 1986). The difficulty adults face in bringing sufficient and adequate food to their young is therefore an important factor in delayed maturity (Lack 1968, Ashmole 1971). Like many seabirds, Damara Terns migrate thousands of kilometers to non-breeding areas and immatures probably remain in these areas for at least two years before they return to their breeding grounds (Ashmole 1971, Harrison 1983, Cramp 1985).

In some tern species, it has been found that within-species variation exists in the age at first breeding with different populations of birds (Mundkur 1992). The age of breeding is decreased when more food is available and competition for nest sites is reduced in some seabird species (Lack 1968). In other seabird species, recruitment has been linked to population size (Crespin *et al.* 2006) and predation risk (Finney *et al.* 2003). Because Damara Terns do not breed in dense colonies and breeding habitat is not a constraining factor in the immense desert coastline, recruitment is unlikely to be affected by competition for nest sites. It is uncertain whether Damara Terns which breed in areas with lower predation risks start breeding at a younger age and this should be explored in further studies.

Because Damara Terns exhibit delayed maturity, high immature survival and lay only one egg with low probabilities of success (Simmons and Braine 1994, Chapter 2), the generational turn-over rate of the species is low. Extended periods are spent by immature and pre-breeding Damara Terns in non-breeding grounds in West Africa, and breeding Damara Terns migrate along *c.* 4000 km of West African coastline twice a year. Given an adult survival rate of 0.87, the estimated number of adults dying per 1000 adults is 130 per year. Given the average fledging success rate of 0.36 (Chapter 2), and a juvenile survival of 0.84 per year, 500 pairs of terns would produce 180 fledglings of which an estimated 107 would survive to three years and 90 to four years. Based on these best current estimates of survival and recruitment, it appears that the breeding productivity is insufficient for population growth.

Migratory seabirds such as the Damara Tern are trapped and sold for food in countries along their migratory route (Braby 2010, Annex 2). In light of these factors, and the apparent shortfall in recruitment, special consideration should be given toward the protection of Damara Tern populations in their non-breeding countries in addition to the conservation management of breeding areas.

Table 4.1: Summary of model selection analysis for age-at-first breeding (alpha) and survival of Damara Terns in Namibia. I examined models that assumed the maximum age to start breeding was 3, 4, 5 or 6 years. Annual survival during the immature period (Sj) was either kept constant (depicted by () in the model descriptions), or assumed to be a linear function of the age when last seen in the nest ((age) in model descriptions), to account for a variable component of nestling mortality because individuals were ringed at different ages). Immature birds could not be trapped, and I examined models where breeder recapture probability (Pa) was either constant (), varied over the years (year), or a linear function of effort (effort). K is the number of estimated parameters.

	Model	AICc	Delta AICc	AICc Weights	K	Deviance
1	{Sj(age)Sa()Pa(effort)alpha(age4)}	682.861	0.000	0.622	8	666.687
2	{Sj(age)Sa()Pa(year)alpha(age4)}	684.352	1.491	0.295	15	653.764
3	{Sj()Sa()Pa(year)alpha(age3)}	688.060	5.198	0.046	12	663.679
4	{Sj()Sa()Pa(year)alpha(age4)}	689.758	6.897	0.020	14	661.244
5	{Sj()Sa()Pa(year)alpha(age5)}	690.864	8.003	0.011	15	660.277
6	{Sj()Sa()Pa(year)alpha(age6)}	692.591	9.730	0.005	16	659.925
7	{Sj(nage)Sa()Pa()alpha(age4)}	698.032	15.171	0.000	7	683.896

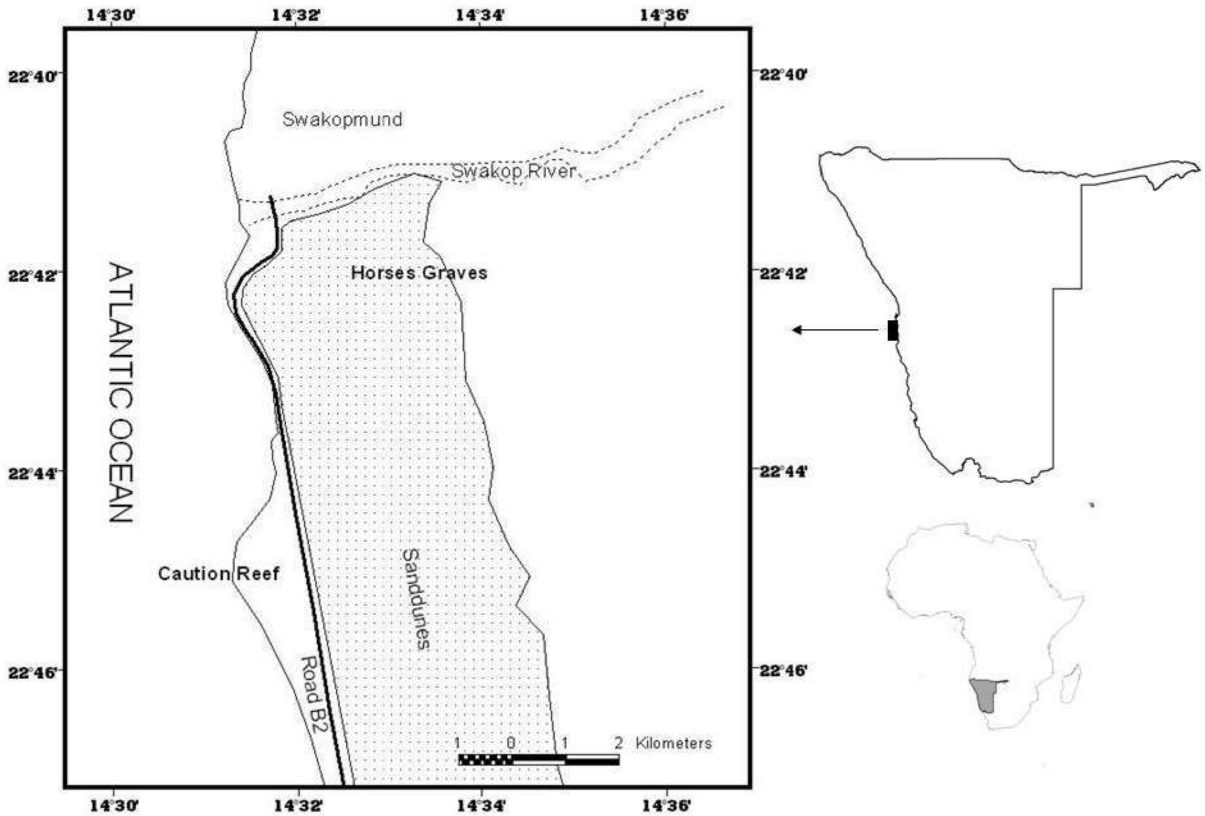


Figure 4.1: Location of two Damara Tern breeding colonies, Caution Reef and Horses Graves, in central Namibia (see Plate 3 for a satellite image).

Chapter 5

Annual survival and dispersal of a seabird adapted to a stable environment: implications for conservation

Nicole Braby

Annual survival and dispersal of a seabird adapted to a stable environment: implications for conservation

Introduction

When habitat becomes unsuitable for a species it is of great conservation interest to know if and how far the individuals will move to resettle in other suitable areas. Knowledge of dispersal is therefore vital when considering wildlife management at the landscape scale. The level to which a species displays fidelity or dispersal depends on the environmental conditions it has evolved in (McPeek and Holt 1992, Clobert *et al.* 2001). We expect such a life-history strategy is dependent on various environmental conditions, such as food availability, predation rates, and how much habitat is available. Generally seabirds are long-lived and faithful to their breeding areas (Beadell *et al.* 2003), but species living in highly variable environments are nomadic and may suffer higher rates of mortality (Renken and Smith 1995a, b; Robinson and Oring 1997). The tendency for individuals to return to areas where they were hatched (natal philopatry), and/or previously bred (breeding philotpatry), has been well-documented for a variety of seabirds, including gulls (Coulson and White 1958, Southern 1977, Southern and Southern 1980, Blockpoel and Courtney 1980, Stenhouse and Robertson 2005) and terns (Austin 1940, 1949, Atwood and Massey 1988, Becker and Wendeln 1997, Spendelow *et al.* 1995, 2008, 2010, Becker *et al.* 2001, Lebreton *et al.* 2003, Devlin *et al.* 2008). Because prior knowledge exists on available nesting sites, food resources and predation pressures, it is often considered a safer strategy for birds to return to a previous breeding site or natal territory than to immigrate to a new area with unknown resources and/or risks (Renken and Smith 1995b). Factors such as predation, low reproductive success and changes in habitat have been implicated in causing breakdowns in fidelity (McNicholl 1975, Erwin 1977, Conover and Miller 1978). However, in spite of the obvious negative impacts of these factors, continued re-use of adversely affected sites has been reported for several seabird species (Austin 1940, 1949, Southern and Southern 1979, Peterson 1980, Southern *et al.* 1980, Southern and Southern 1982). The level to which species display fidelity to their breeding sites is important in understanding the management and protection of these species.

Damara Terns *Sterna balaenarum* breed predominantly on the coastline where the harsh Namib Desert meets the cold and dynamic Benguela current (Simmons and Braine 1994). Damara Terns feed primarily inshore where physical fluctuations result in biological patchiness and high variability (Branch et al. 1987). Recruitment of prey species like Anchovy *Engraulis encrasicolus* in the northern Benguela system shows high inter-annual variability (Boyer *et al.* 2001). However, the Benguela system is not as variable as say, the Humboldt system, and seabirds here are generally adapted to a more stable supply of food (Crawford *et al.* 2006). I would expect that Damara Terns have adapted to this stable food supply by displaying high annual survival and fidelity to their breeding sites. In addition, although there is ample available undisturbed habitat along the coastline of Namibia, Damara Terns are found breeding in specific areas (Clinning 1978). However, predation rates are high and predation has been considered the major driving force in the evolution of the unique one-egg clutch trait of this tern (Frost and Shaughnessy 1976; Clinning 1978). High or fluctuating predation has resulted in lower fidelity in some other tern species, and even caused mass periodic dispersal in other species of terns (Oro et al. 1999). The Damara Tern is globally Near-threatened (IUCN 2009) and it is the only small tern that predominantly lays one egg (Simmons and Braine 1994; de Villiers and Simmons 1997). During the non-breeding season (May–September) Damara Terns migrate to West African countries such as Gabon, Cameroon and Nigeria (Williams et al. 2004). The Benguela Upwelling System is currently undergoing changes due to over-fishing and climate change (Clark 2006). In addition, Damara Tern breeding grounds are threatened by off-road driving and coastal development (Braby et al. 2001; Braby et al. 2009; RJ Braby unpubl data). It is thus becoming increasingly important to understand the life-history adopted by the species. Few demographic parameters exist for the Damara Tern and these are necessary to test whether the current management approach of protecting specific breeding sites is appropriate. The objective of this chapter is to provide estimates of (a) adult survival and (b) dispersal probabilities of Damara

Terns based on 10 years of capture-mark-recapture data of adult Damara Terns breeding at two close-proximity colonies along the central coastline of Namibia.

Study area

This study took place at Caution Reef (22°44S, 14°32E) and Horses Graves (22° 42'S, 14° 33'E) south of Swakopmund within the Dorob National Park (Figure 4.1 in Chapter 4). The habitat at Caution Reef consists mainly of open and sparsely vegetated sandy plains with a raised gravel ridge through the centre (Braby *et al.* 2001). Horses Graves comprises a series of barchan, linear, and crescent dunes separated by gravel plains in which the terns breed (Braby *et al.* 2001). For a more detailed description of the study area, see Chapter 1.

Both Caution Reef and Horses Graves are fenced off from the public to ensure minimal disturbance from off-road driving. These two areas are protected from coastal development.

Methods

Incubating adults were trapped on their nests using a netted snap-trap controlled remotely by a trigger from a distance of up to 200 m. Once successfully trapped, SAFRING metal rings were placed on the right leg; and a unique combination of colour rings pertaining to the breeding season were placed on the left leg. Damara Terns were trapped between October and February, when they are breeding during the austral summer months. I used data collected on 214 adult terns between October 2000 and December 2009, defining the survival intervals to run from 1 October until 30 September of the following year.

Multi-state capture-mark-recapture models (Spendelow *et al.* 1995) were used to estimate adult survival rate at the two colonies, and the annual movement probabilities between them. These models are extensions of classical capture-mark-recapture models (Lebreton *et al.* 1992) and provide estimates of survival and movement while accounting for the recapture probabilities at the two colonies.

The models consist of three components. The first estimates local survival, which is the probability of surviving from one year to the next, and staying in the study area. I cannot distinguish between mortality and permanent emigration to sites not studied here, and my survival estimates will therefore tend to be biased slightly low. The second component estimates recapture, which is the probability of capturing an individual given that it is alive and in the study area. The third component estimates movement between the colonies.

The most general model that could be fitted to the data allowed all components to differ between the colonies and the recapture rates to vary over the years. Simplified versions of this model were considered and sample-size adjusted Akaike's information criterion (AICc) was used to evaluate model performance (Burnham and Anderson 2002). All models were fitted in program MARK 6.0 (White and Burnham 1999).

The models used make the assumption that individuals have similar survival, recapture, and movement probabilities. This assumption was tested for the most general model using the median-$\hat{c}$ procedure in program MARK. This test showed little sign of overdispersion ($\hat{c}$=1.19, SE=0.03), and thus suggested that this model captured the structure in the data well. Parameter estimates in the text are given with the 95% confidence interval in brackets.

Results

Model selection based on AICc favoured a model that kept the annual survival rate constant across colonies, assumed that the recapture rate was a linear function of effort (number of hours spent trapping per season), and that movement probabilities were equal in both directions (Model 1, Table 4.1). According to this model, annual local survival was 0.88 (0.73–0.96). The annual movement probability was 0.06 (0.03–0.12), and the recapture probabilities were positively related to effort and ranged from 0.041 (0.023–0.076) to 0.18 (0.10–0.30).

Model 2 was 2.4 times (ratio in AICc weights) less well supported by the data than the best model. According to this model, terns had lower annual survival at Horses Graves colony (0.86; CI: 0.69 to 0.95) than at Caution Reef colony (0.91; CI: 0.66 to 0.98).

Discussion

My results show that Damara Terns have high survival rates and are faithful to their breeding sites, life history traits typical of seabirds adapted to stable environments (Beadell *et al.* 2003). Despite variability of prey in the near-shore ecosystem where Damara Terns feed, the Benguela Upwelling System is abundant in prey species such as Anchovy (Crawford *et al.* 2006). The most similar upwelling system, in the Humboldt Current, experiences more frequent El Niño perturbations and seabirds feeding on the same species of prey there have a demography that enables them to recover more rapidly from population decreases due to these perturbations (Crawford *et al.* 2006). No comparative demographic parameters exist for the Peruvian Tern *Sterna lorata*, an ecological equivalent which is adapted to a more variable environment than the Damara Tern (Crawford *et al.* 2006). Such a comparison would be necessary to determine how similar species have adapted to different environments. However, my results conform with the suggestion by Crawford *et al.* (2006) that seabirds reliant on the Benguela system are adapted to a more stable supply of food.

My annual survival estimate of 0.88, albeit with wide confidence intervals owing to a relatively small data set, is consistent with published estimates of adult annual survival in other terns and gulls, among which survival estimates are typically high (Table 5.2). The estimated annual survival probability is probably lower than the true value because I could not distinguish between mortality and permanent emigration from the study area. To determine the relative importance of permanent emigration will require a study of inter-colony movement between all major colony sites. No large colonies exist in the vicinity of our study area, but it is possible that three small colonies (<30 pairs) within 30 km of the study site may have absorbed a small number of emigrants. Reed and Oring (1993) found that expanding their study site gave a more accurate picture of site fidelity and dispersal in Spotted Sandpipers *Actitis macularius*. However, previous multi-site studies on breeding terns showed that terns nesting on colonies closer together experience higher rates of movement than those further apart (Spendelow *et al.* 1995, Devlin *et al.* 2008). The two colonies in this study were extremely close together (*c.* 4 km), and very little movement was observed between the two sites. Due to this low movement probability I assume that there is little emigration of Damara Terns from colonies, but a multi-site study would be required to test this assumption. Spendelow *et al.*

(2010) found that a small sample of Roseate Terns, even after breeding in one region for many years, may move up to 400 km to another region to breed.

The low local dispersal probability of 0.06 indicated that Damara Terns show fidelity to the same breeding area. Low dispersal probabilities may have evolved in the species as a result of previous knowledge of breeding sites, like associated predation risk factors and prey availability. Damara Terns suffer high predation rates, even at the study areas in question (Braby *et al.* 2001, Braby et al. 2009, Chapter 2). Generally, increased predation rates at tern colonies result in low site fidelity, or mass movement from breeding areas (Oro *et al.* 1999, Spendelow *et al.* 2002). It thus comes as a surprise that Damara Terns display little dispersal from their study sites. This tern may have evolved with high rates of predation, and thus shows fidelity to sites due to learned and acquired knowledge of predation risks at these sites. Little or no change to habitat occurs at either breeding sites (Horses Graves and Caution Reef, pers. obs.) and unpredictable breeding habitat usually yields little fidelity (Robinson and Oring 1997). For instance, California Least Terns *Sterna antillarum browni*, which only occupy several secure breeding sites, display a 79% rate of return to the same breeding site yearly (Atwood and Massey 1988), but interior Least Terns *Sterna antillarum*, which breed on sandbars and islands in rivers (a habitat that is continuously changing), display yearly return rates of only 42% (Renken and Smith 1995b). Species which are not accustomed to changing habitats are generally more site faithful and they may fail to move if their breeding habitats are impacted by humans, which would therefore reduce their ability to breed successfully (Southern and Southern 1982).

Prior to this study no details of the demography of Damara Terns were known, which in the past has (1) prevented basic population modeling, and (2) prevented meaningful comparisons with other terns. Such comparisons could help determine whether or not species considered closely related share important demographic characteristics and would better our understanding of similar life-history strategies (Stenhouse and Robertson 2005). Demographic parameters also help us find appropriate conservation approaches to ensure the species survival. Damara Terns migrate a total of *c.* 8000 km each year and breed in harsh desert environments with high rates of predation, but feed in highly productive waters where food is abundant (Crawford *et al.* 2006). Low breeding success (probability of less than 0.4 of nests surviving predation per season per pair, Chapter 2), high annual survival and fidelity to breeding sites may have evolved as a response to these conditions. In light of this, the most important management approach for the population viability for seabirds such as the Damara Tern, which display high rates of fidelity, may be long-term maintenance and protection of current colony sites.

Table 5.1: Summary of model selection analysis for survival and movement of Damara Terns in Namibia. The model components were survival (Sh at Horses Graves colony, and Sc at Caution Reef colony), recapture probability (Ph and Pc at the two colonies, respectively), movement from Horses Graves to Caution Reef (Ψhc), and movement in the opposite direction (Ψch). I considered variable recapture rates over the years (year), or as a linear function of effort (effort; number of hours spent trapping). K is the number of estimated parameters.

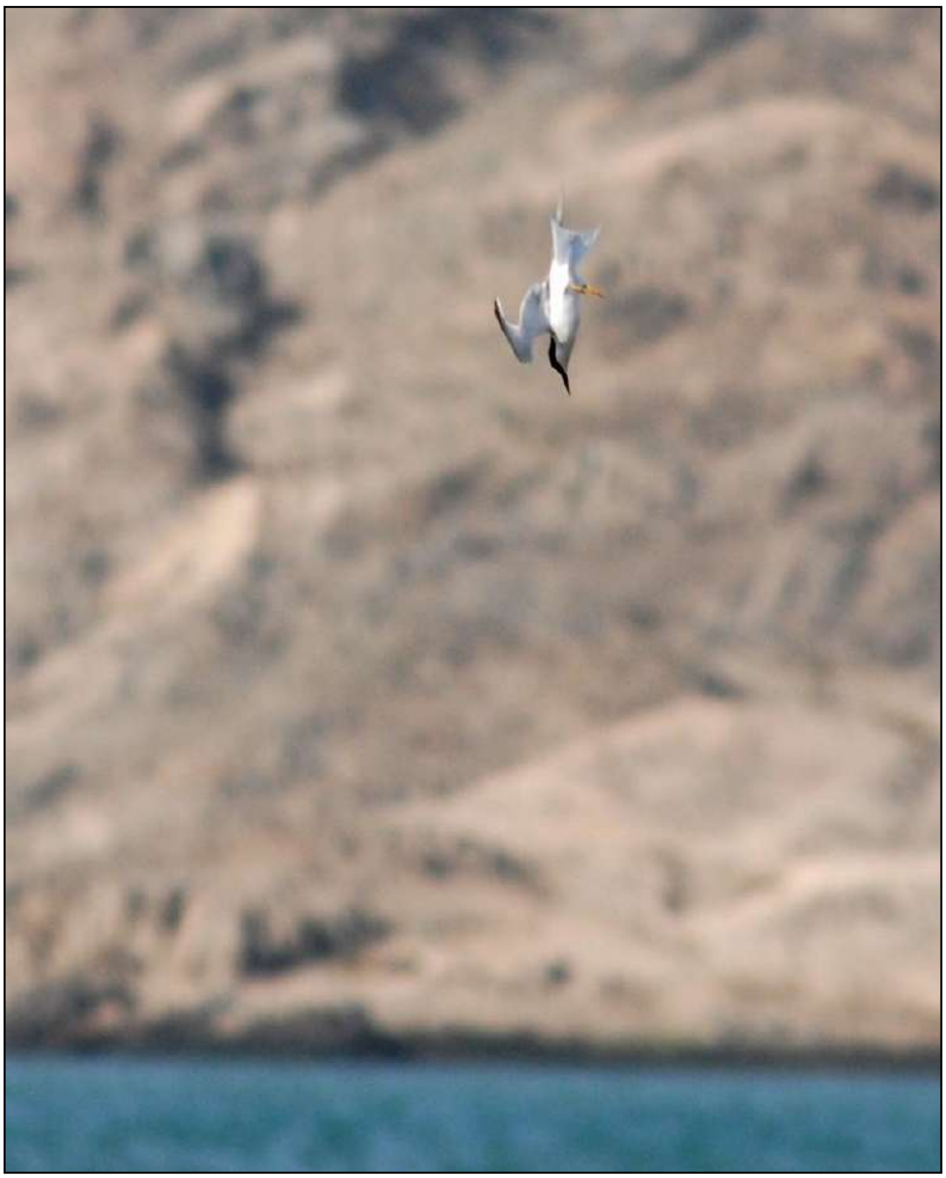
	Model	AICc	Delta AICc	AICc Weights	K	Deviance
1	{Sh()=Sc()Ph(effort)=Pc(effort) Ψhc()=Ψch()}	484.675	0.000	0.573	4	156.475
2	{Sh()Sc()Ph(effort)=Pc(effort)Ψhc()=Ψch()}	486.383	1.709	0.244	5	156.103
3	{Sh()Sc()Ph(effort)=Pc(effort)Ψhc()Ψch()}	488.136	3.461	0.102	6	155.758
4	{Sh()Sc()Ph(effort)Pc(effort)Ψhc()Ψch()}	489.924	5.249	0.042	7	155.432
5	{Sh()=Sc()Ph(year)=Pc(year)Ψhc()=Ψch()}	490.310	5.636	0.034	10	149.372
6	{Sh()Sc()Ph(year)=Pc(year)Ψhc()Ψch()}	494.670	9.995	0.004	12	149.345
7	{Sh()=Sc()Ph()=Pc()Ψhc()=Ψch()}	497.103	12.428	0.001	3	170.967
8	{Sh()Sc()Ph(year)Pc(year)Ψhc()Ψch()}	505.763	21.088	0.000	20	142.148

Table 5.2: Estimates of annual survival rates of terns and gulls. 95% confidence intervals (CI), or standard errors (SE), are given when available.

	Survival Rate	Reference
Sternidae		
Damara Tern *Sterna balaenarum*	0.88 (0.73-0.96)	This study
Least Tern *Sterna antillarum*	0.85 (SE=0.06)	Reuken and Smith 1995a
Common Tern *Sterna hirundo*	0.88 (SE=0.04)	Nisbet and Cam 2002
	0.91 (0.87-0.97)	Becker et al. 2001
Arctic Tern *Sterna paradisaea*	0.74-0.84	Spendelow et al. 1995
	0.704–0.960	Devlin et al. 2008
Roseate Tern *Sterna dougallii*	0.8501	Lebreton et al. 2003
	0.0835 (SE=0.006)	Spendelow et al. 2008
	0.850	O'Neill et al. 2008
Sooty Tern *Onychoprion fuscatus*	0.91 (SE=0.01)	Feare and Doherty 2004
Royal Tern *Thalasseus maximus*	0.95	Collins and Doherty 2006
Laridae		
Kelp Gull *Larus dominicanus*	0.84	Altwegg et al. 2007
Herring Gull *Larus argentatus*	0.826-0.975	Pons and Migot 1995
Sabine's Gull *Xema sabini*	0.89 (SE=0.03)	Stenhouse and Robertson 2005
Ivory Gull *Pagophila eburnea*	0.86 (SE=0.04)	Stenhouse et al. 2004
Black-legged Kittiwake *Rissa tridactyla*	0.88 (SE=0.02)	Harris et al. 2000
	0.80 (SE=0.03)	Oro and Furness 2002
Black-headed Gull *Larus ridibundus*	0.90 (0.86-0.92)	Prévot-Julliard et al. 1998

Chapter 6

Prey capture success and chick diet of Damara Terns *Sterna balaenarum* in southern Namibia



Jessica Kemper

Prey capture success and chick diet of Damara Terns *Sterna balaenarum* in southern Namibia

Introduction

The success of foraging seabirds is influenced by prey availability which is a function of both prey abundance and prey accessibility (Henkel 2006). Especially for seabird species feeding close to the coastline, prey accessibility may be influenced by a number of environmental factors (Ainley 1977, Holm and Burger 2002, Peste *et al.* 2004, Henkel 2006, Baptist and Leopold 2010). Many terns feed by plunge-diving which is visually associated and requires considerable skill (Williams and Meyer 1986). I postulate that environmental factors affecting one plunge-diving tern, the Damara Tern *Sterna balaenarum*, include tidal phase, wind speed, water clarity, cloud cover and water depth.

Tidal phase and wind speed are known to influence the feeding ecology of terns (Dunn 1973, Cramp and Simmons 1983, Hulsman *et al.* 1989, Becker and Specht 1991, Frank 1992, Frank and Becker 1992, Becker *et al.* 1993, Brenninkmeijer *et al.* 2002, Peste *et al.* 2004, Paiva *et al.* 2008). Prey capture success or chick provisioning has generally been found to increase at low or receding tides (Peste *et al.* 2004, Brenninkmeijer *et al.* 2002, Paiva *et al.* 2006b), but some studies have shown increased success at high tide (Hulsman 1976, Burger 1982). Taylor (1983) found a decreasing capture rate at higher wind speeds, but Dunn (1972, 1973) found that capture rates increased with increasing wind speed.

Many studies have shown the effect of water clarity on the distribution and ecology of feeding seabirds (Ainley 1977, Haney and Stone 1988, Safina and Burger 1988, Abrahams and Kattenfield 1997, Holm and Burger 2002, Day *et* *al.* 2003, Henkel 2006, Baptist and Leopold 2010). One would expect that in turbid water prey are more difficult to locate, but in clear water predators may be visible to prey too. Baptist and Leopold (2010) found a non-linear relationship of prey capture success in increasing water turbidity, with success least in very clear and very turbid waters, and greatest for moderate levels of turbidity.

In relation to cloud cover, Hawksley (1950, 1957) and Lemmetyinen (1972) showed that Arctic Tern *Sterna paradisaea* chicks gained weight on clear days but generally lost weight on foggy days. However, neither author considered prey capture success directly. Factors affecting prey capture success are important to study because they can influence various aspects of breeding success (Peste *et al.* 2004).

Damara Terns *Sterna balaenarum* feed mainly by plunge-diving into water (Simmons and Braine 1994). Feeding terns can be found in sheltered bays, lagoons, estuaries and in the surf zone along the open coast (Frost and Shaughnessy 1976, Clinning 1978, Williams and Meyer 1986, Braby *et al.* 1992). Small samples of prey items collected from chick regurgitations (Clinning 1978, Simmons and Braine 1994) have been found to be similar to that of related species, such as Peruvian Terns *Sterna lorata* (Zavalaga *et al.* 2008), and Little Terns *Sterna albifrons* (Bogliani *et al.* 1994, Catry *et al.* 2006, Paiva *et al.* 2006b).

I studied the prey capture success of Damara Terns breeding at two localities during two breeding seasons in southern Namibia as a function of six variables: wind speed, tidal phase, water clarity, cloud cover, water depth and locality. This chapter also presents new information on the diet of Damara Tern chicks in Namibia.

Methods and study area

Foraging observations

The prey capture success of Damara Terns was measured during two consecutive breeding seasons in 2007/08 and 2008/09 (October to March) at two breeding localities in southern Namibia: Grosse Bucht (26°43′S, 15°40′E) and Elizabeth Bay (26°55′S, 15°14′E, Figure 6.1). The environments of each area are described in Chapter 1. Both bays are affected by winds that can exceed 50 km/hour.

Observations on foraging terns were made throughout two breeding seasons, and during daylight hours. The observer watched from a vehicle or from the beach. Once a Damara Tern was recorded foraging, it was watched continuously using 8×42 binoculars. Its activities were timed (to the nearest second) until it flew back to the colony, landed, or flew out of sight. A single foraging bout consisted of a tern looking down while flying or hovering 1–5 m above the sea surface. The numbers of successful and unsuccessful dives were recorded during each foraging bout.

Five environmental conditions were recorded during each foraging bout: tidal phase, wind speed, water clarity, cloud cover and feeding location.
Tidal phase; four tidal phases were categorized: high tide (90 minutes before HT until 90 minutes after HT), receding tide (RT: next three hours), low tide (90 minutes before LT until 90 minutes after LT), and incoming tide (IT: next three hours).
Wind speed was estimated in the field (four categories; 1: calm to gentle breeze, 2: moderate breeze, 3: wind, 4: strong wind). When the observed descriptions of wind speeds were checked against the measured wind speeds at the weather station at Diaz Point (26°38′S, 15°05′E), the mean wind speeds in the four categories were approximately 10, 20, 30 and 45 km/hr

respectively. Using the midpoints between these values (15, 25 and 37.5 km/hour), as boundary points, there were only eight occasions (of 119 observations) when the assigned category differed from the measurement. For all except one of these, the wind speed at Diaz Point was greater than in the study area. Diaz Point is particularly exposed to winds, and is 11 km north of Grosse Bucht, and 33 km north of Elizabeth Bay. Wind conditions can vary considerably between these areas, depending on wind direction.
Water clarity was classified on a three-point scale at Elizabeth Bay, where clarity was affected by sediments deposited into the bay as part of the diamond mining extraction process (Chapter 7). Water colour was used to estimate water clarity: a gradient was adopted, ranging from one to three, where 1=least turbid water (blue water) and three 3=most turbid water (brown waters). It must be noted that least turbid water here is still relatively turbid due to sediment deposits into the bay (and the natural turbidity of the area, CSIR 1996, 1997, 1998, Chapter 7).
Cloud cover was estimated in the field (a scale of 0–4; 0= no cloud, 4= completely overcast).
Feeding location was either Elizabeth Bay or Grosse Bucht.
Adults observed foraging were assigned to water depth; the shallows, in the surf zone, or behind the breakers.

A generalized linear model with a binomial distribution and a logistic link function was used to relate the number of successful dives (i.e. prey capture success) within the total number of dives of a foraging bout to the explanatory variables observed at the time of the bout. Within each foraging bout, the probability of success of each dive was therefore modelled as having the same explanatory variables. Variables considered were wind speed, tidal phase, water clarity, cloud cover, water depth and locality; for each variable, the first level was set as the baseline level in the generalized linear model. Analyses were performed in GenStat and the Akaike Information Criterion was used to guide model selection (GenStat 12 Committee 2009). A generalized linear model with a Poisson distribution and logarithmic link function was used to relate the total number of dives counted during the observation period to wind speed. Because water clarity was only measured at Elizabeth Bay, the dataset for all explanatory variables (including water clarity) was analysed separately when investigating the influence of water clarity on prey capture success. The observation period was used as an offset variable (GenStat 12 Committee 2009).

Collection of prey items

Chick regurgitations and prey items dropped by adults while provisioning their chicks were collected at the following localities and time periods: Ogden Rocks (21°06′S, 13°34′E) on 19 December 1992, Durissa Bay Pans (21°15′S, 13°41′E) and White Stones (21°39′S, 13°56′E) during December 2009–March 2010, Caution Reef (22°44'S, 14°32'E) during October 1994–March 1995, Hottentots Bay (26°14′S, 14°59′E), Grosse Bucht, Elizabeth Bay and Marmora Pan (27°45′S, 15°34′E) during October 2007–April 2008 and October 2008–April 2009 (Figures 1.1–1.3 and 1.5 in Chapter 1).

Bomb calorimetry and energy content of fish

In order to estimate the energy content of the fish species fed to chicks, fresh specimens were collected using a small net from foraging areas at Grosse Bucht. Five specimens were measured (standard length), washed with fresh water and frozen. To determine the energy content, specimens were thawed and dried in an oven at 60° C until no further weight loss occurred (*c.* 7 days). Each dried specimen was crushed to dust in a mortar. These were converted into discs in a press and used to determine the calorific content in the Cal 2k bomb calorimeter. The energy content was given by the calorimeter in kilojoules per gram of dry mass.

Results

Prey capture success

Damara Terns were always observed foraging at sea. During 105 hours of observations for foraging terns, 389 foraging bouts, lasting a total of 16.6 hours, were observed. Within these 389 foraging bouts there were 865 dives of which 305 were successful (30.5%, SD=3.1%). The mean time spent foraging by a Damara Tern during a foraging bout was 153 seconds (SD=124 seconds, n=389).

Prey capture success increased with tide, and was highest at high tide (Modelled Probability of Prey Capture Success (PCS)=0.65, Figure 6.2A). The prey capture success at incoming tide was significantly lower than at high tide (the baseline level of the model) (P=0.008, Table 6.1; PCS=0.45, Figure 6.2A). The prey capture success at receding tide was also significantly lower than at high tide (P=0.001, Table 6.1; PCS=0.41, Figure 6.2A). In relation to high tide (baseline), the prey capture success was lowest at low tide (P<0.001, Table 6.1; PCS=0.33, Figure 6.2A).

There was a general tendency for prey capture success to increase with increasing wind speed. For wind level 1 (the baseline level of the model, *c.* 10 km/hr), PCS was 0.45 (Figure 6.2B). In relation to this baseline level, prey capture success was highest in wind 4 (*c.* 45 km/hr, P=0.001, Table 6.1; PCS=0.63, Figure 6.2B). The prey capture success was higher in wind 2 (*c.* 20 km/hr, PCS=0.47, Figure 6.2B) and in wind 3 (*c.* 30 km/hr, PCS=0.49, Figure 6.2B) than in wind 1. However, these were not significant (wind 2, P=0.769; wind 3; P=0.487; Table 6.1). The dive rate (dives per minute), however, decreased with increasing wind speed (Table 6.2). The product of the dive rate and the modelled prey capture success provides an estimate of prey capture success rate (successful dives per minute), and this decreased with increasing wind speed (Table 6.2).

At Elizabeth Bay, water clarity was a significant explanatory variable in predicting prey capture success (Table 6.3, Figure 6.3). In relation to water clarity 1 (the baseline level of the model, least turbid water, PCS=0.37, Figure 6.3), the prey capture success was significantly lowest in water clarity 3 (most turbid water, P<0.001, Table 6.3; PCS=0.12, Figure 6.3). The prey capture success in water clarity 2 was also lower than the prey capture success in water clarity 1 (P=0.008, Table 6.3; PCS=0.24, Figure 6.3).

Cloud cover, water depth and locality (i.e. Grosse Bucht and Elizabeth Bay) were not significant explanatory variables in predicting prey capture success. Interactions between explanatory variables were not significant either.

Diet composition

A total of 55 prey items were collected at seven localities along the Namibian coast over 18 years (Table 6.4). Five could not be identified. The 50 identifiable prey items represented 15 fish species in 12 families, of which the most abundant was the Cape Silverside *Atherina breviceps* (18%, n=10). However, this species was not represented in any of the prey items found in the breeding colonies of southern Namibia. Species from the family Blennidae (14.2%, n=8), Southern Mullet *Liza richardsonii* (12.5%, n=7), and Cape Anchovy *Engraulis encrasicolus* (10.7%, n=6) were among the most abundant species collected. The mean length of 27 whole prey items was 5.67 cm (SD=2.56 cm, range=2.27–10.84 cm). The fresh masses of three items were obtained: two Cape Anchovy weighed 4 g (length=7.48 cm) and 3.48 g (length=9.26 cm) and a needlefish sp. (Belonidae) weighed 2.7 g (length=9.20 cm).

Bomb calorimetry and calorific value of fish

The five fresh specimens collected from foraging areas at Grosse Bucht were Southern Mullet. Of these five specimens, I was able to ascertain the energetic contents of four. The mean energetic content of these four specimens (mean length=5 cm) was 14.84 kJ/g dry mass (Table 6.5).

Discussion

Prey capture success

Tidal phase, wind speed and water clarity significantly affected the prey capture success of foraging Damara Terns, but cloud cover, water depth and feeding locality did not. The data showed that Damara Terns had an overall prey capture success of 30.5%. Simmons and Braine (1994) found a prey capture success of only 14% of four observations of foraging Damara Terns in northern Namibia. This low prey capture success compared to mine may be attributed to a smaller sample size in their study.

This study found that Damara Terns dived most successfully at high tide. Peste *et al.* (2004) found a higher prey capture success in foraging Little Terns during the receding tide, and Davies (1981) observed chicks being fed mostly in the last hours of the receding and incoming tide. Brenninkmeijer *et al.* (2002) estimated a better food intake rate for Little Terns during the receding tide. Because these studies were mainly conducted at lagoons, estuaries and salinas, the narrow channels of water which connect to the ocean would be greatly affected by the tide. Perhaps during the receding tide fish become more grouped and conspicuous in these channels and probably easier to catch (Peste *et al.* 2004). Paiva *et al.* (2006b) found that number of foraging Little Terns was higher during low tide; however this was not the case in this study where the number of Damara Terns was similar across all four tidal phases. Common Terns in Jamaica fed primarily during high tides

(Burger 1982). Hulsman (1976) had similar findings with Black-naped Terns *Sterna sumatrana*. However, Erwin (1977) found no effect of tides on Common Terns feeding in Maryland. Burger (1982) postulated that during low tides many areas of the bay may be exposed thus decreasing feeding habitat; and fish may tend to move back into the shallow areas of the bay with an incoming tide. Damara Terns frequently dived in shallow waters but water depth did not significantly impact prey capture success. Both Elizabeth Bay and Grosse Bucht have areas exposed at low tides and these areas are relatively shallow at high tide. Perhaps during high tide there is more feeding habitat, thus reducing competition between terns within the feeding grounds in the bays studied.

Wind speed significantly affected the prey capture success of foraging Damara Terns. Surprisingly, increased prey capture success correlated with strong winds. However, dive rate and prey capture success rate was highest in calm or light breeze conditions. Dunn (1972, 1973) found increasing prey capture success with increasing wind speed. Prey capture success in this study was higher at moderate and strong wind conditions compared with calm sea. This could be explained by the visibility of the predator, which is strengthened by the more vigorous hovering action at low wind speed and by the reflective properties of a smooth sea surface (Dunn 1973). Dive rates and prey capture success rates increased with decreasing wind speeds. Diving more frequently in calm conditions may be a result of a lower energetic cost per dive in calm conditions versus windy conditions. Taylor (1983) also found that dive rates decreased significantly with increasing wind speed in Common and Sandwich Terns *Sterna sandvicensis* but prey capture success showed no significant relationship. Paiva *et al.* (2006b) found that wind speed affected delivery rate of prey to Little Tern chicks. Stienen *et al.* (2000) reported an increasing chick provisioning rate in the Wadden Sea at increasing speeds of around 30 km/hr but found a rapid decline at speeds over

50 km/hr. This was beyond the scope of my study, but wind conditions are more likely to affect flight speed to and from the breeding area than foraging success itself. Dunn (1975) postulated that under most wind conditions, however, the fishing success of adult terns is not altered sufficiently to influence tern chicks' daily intake of food.

I found that prey capture success was highest in least turbid water at Elizabeth Bay. Previous studies have suggested that Damara Terns avoid murky, sediment-filled water (Simmons 2005a), but these have been mostly based on small sample sizes (10 foraging bouts, Simmons 2005a, b). Henkel (2006) suggested that plunge-divers should be associated to clear waters where prey can be located visually from a distance but contemplated studies that showed species like terns prefer more turbid water (Haney and Stone 1988, Safina and Burger 1988). Prey may avoid the surface layers in clear waters to escape from plunge-diving predators. Plunge-divers like terns may prefer turbid waters where prey may concentrate in the upper layers. The greatest upwelling cell in the Benguela Upwelling System is found near Lüdertiz (Shannon 1989). Natural water turbidity is thus generally quite high around Grosse Bucht and Elizabeth Bay (CSIR 1996, 1997, 1998), both of which are in relatively close proximity to Lüderitz. Water turbidity at Elizabeth Bay is also increased due to discharging fines into the bay as part of the diamond mining process (Chapter 7). Damara Terns dived for prey more successfully in the least turbid water here, which arguably is still quite murky. I suspect that prey capture success would decrease if the water was very clear. This non-linear relationship was found in a study of Sandwich Terns in the North Sea (Baptist and Leopold 2010).

Chick diet and energy content

At least nine new species were found in the chick diet of Damara Terns which had not been found in two previous studies of Damara Tern chick diet

(Clinning 1978, Simmons and Braine 1994). Both Clinning (1978) and Simmons and Braine (1994) found species that were collected in this study too, including larval Blenny, Mullet, Anchovy and Needlefish. The diet of Damara Tern chicks is similar to that described by Catry *et al.* (2006) for fish fed to Little Tern chicks (e.g. *Artherina* sp., *Mugil* sp., Blennidae, Gobidae), by Elliot *et al. (*2007) for the diet of the California Least Tern *Sterna antillarum browni* (e.g. *Atherina* sp., Gobidae, *Engraulis* sp.), and by Zavalaga *et al.* (2008) for the diet of the Peruvian Tern (e.g. *Atherina* sp., *Engraulis* sp., *Scomberesox* sp.). This emphasises the ecological similarities between these small terns.

Cape Silverside occurs all along the coastline of south-western Africa (Smith and Haemstra 1986) but none were collected from chick regurgitations in southern Namibia. This absence of Cape Silverside may have been attributable to a small sample size. Most of the Cape Silverside specimens were collected from the central coastline where Damara Terns feed predominantly around the Swakop River estuary (pers. obs). A possible reason for this is that the Cape Silverside is one of the few marine fish that can withstand the reduction in salinity within the estuarine environment (Smith and Haemstra 1986) and thus may be the most common prey species for Damara Terns feeding in estuarine environments. The energy content of Southern Mullet specimens (14.84 kJ/g dry mass) was lower than that for Mugilidae species fed to Little Tern chicks in Portugal (20.35 kJ/g dry mass, Paiva *et al.* 2006b). Lower energy content of food may have implications on chick growth and other aspects of breeding biology (Chapters 2 and 3).

This study confirms the importance of the impact of environmental conditions on feeding success of plunge-divers. Environmental conditions affecting feeding success are likely to be linked to Damara Tern breeding numbers and reproductive success in any given season.

Table 6.1: Results of the generalized linear model with binomial distribution and logit link function relating the prey capture success of Damara Terns at two breeding areas in southern Namibia to two explanatory variables, tidal phase and wind speed. Both variables are categorical, with baseline categories, for which the estimated regression coefficients are set to zero.

Explanatory variable	**Coefficient**	**S.E.**	$t_{388,2}$	**P-value**
Constant	–0.209	0.283	–0.74	0.460
Tide high	0	0	0	–
Tide receding	–0.906	0.285	–3.18	0.001
Tide low	–1.270	0.303	–4.19	<0.001
Tide incoming	–0.735	0.275	–2.67	0.008
Wind 1 (calm breeze)	0	0	0	–
Wind 2 (moderate breeze)	0.071	0.241	0.29	0.769
Wind 3 (wind)	0.147	0.211	0.69	0.487
Wind 4 (strong wind)	0.754	0.232	3.25	0.001

Table 6.2: Percentage of successful dives, dive rate (dives per minute) and prey capture rate (prey captured per minute) in relation to wind speed for foraging Damara Terns in southern Namibia. The sample size is the number of foraging bouts observed.

Wind category	**Sample Size**	**Successful dives (%)**	**Dive rate**	**Prey capture rate**
Wind 1 (calm breeze)	90	24.0	1.366	0.612
Wind 2 (moderate breeze)	73	27.9	0.935	0.436
Wind 3 (wind)	126	28.4	0.814	0.395
Wind 4 (strong wind)	100	45.8	0.598	0.379

Table 6.3: Results of the generalized linear model with a binomial distribution and a logit link function showing modelled prey capture success of Damara Terns at Elizabeth Bay in southern Namibia in relation to three explanatory variables; tidal phase, wind speed and water clarity. Because water clarity was only measured at Elizabeth Bay (due to turbidity increase through diamond mining processes), a separate analysis was performed for Elizabeth Bay. All three variables are categorical, with baseline categories, for which the estimated regression coefficients are set to zero. The sample size is the number of foraging bouts observed.

Explanatory variable	Sample size	Coefficient	SE	$t_{176,2}$	P-value
Constant		0.279	0.385	0.72	0.469
Tide high	33	0	0	0	–
Tide receding	111	–1.120	0.403	–2.78	0.005
Tide low	107	–1.893	0.470	–4.03	<0.001
Tide incoming	138	–0.825	0.421	–1.96	0.05
Wind 1 (calm breeze)	90	0	0	0	–
Wind 2 (moderate breeze)	73	0.790	0.479	1.65	0.099
Wind 3 (wind)	126	0.631	0.359	1.76	0.078
Wind 4 (strong wind)	100	0.987	0.353	2.80	0.005
Water clarity 1 (least turbid)	49	0	0	0	–
Water clarity 2	55	–0.605	0.286	–2.11	0.035
Water clarity 3 (most turbid)	72	–1.434	0.327	–4.38	<0.001

Table 6.4: Damara Tern chick diet composition in Namibia as determined from chick regurgitations and food dropped by adults.

Family	Common name	Latin name	Prey items (n)	Place and season
Atherinidae	Cape Silverside	*Atherina breviceps*	10	Caution Reef (94/95, n=5) White Stones (09/10, n=1) Durissa Bay Pans (92/93, n=2; 09/1, n=2)
Belonidae	Needlefish sp.	*	2	Durissa Bay Pans(92/93, n= 1) Ogden Rocks (92/93, n=1)
Blennidae	Larval Blenny sp.	*	2	Caution Reef (94/95, n=2)
	Horned Blenny	*Parablennius cornutus*	6	Caution Reef (94/95, n=6)
Clinidae	Klipfish sp.	*	2	Caution Reef (94/95, n=2)
	Super Klipfish	*Clinus superciliosus*	1	Caution Reef (94/95, n=1)
Engraulidae	Cape Anchovy	*Engraulis encrasicolus*	6	Hottentots Bay (08/09, n=4) Caution Reef (09/10, n=1) Durissa Bay (92/93, n=1)
Gobidae	Goby sp.	*	1	Caution Reef (94/95, n=1)
Gonorynchidae	Beaked Sandfish	*Gonorhynchus gonorhynchus*	1	Hottentots Bay (08/09, n=1)
Merlucciidae	Hake sp.	*	3	Hottentots Bay (08/09, n=1) Marmora Pan (07/08, n=2)
Mugilidae	Southern Mullet	*Liza richardsonii*	6	Marmora Pan (07/08, n=2) Grosse Bucht (08/09, n=2) Hottentots Bay (07/08, n=1) Caution Reef (94/95, n=1)
Scomberesocidae	Saury	*Scomberesox saurus scomberoides*	2	Hottentots Bay (08/09, n=2)
Seranidae	Comber	*Serranus cabrilla*	4	Marmora Pan (07/08, n=4)
Sparidae	Seabream sp.	*	1	Grosse Bucht (08/09, n=1)
	Blacktail	*Diplodus sorgus capensis*	3	Caution Reef (94/95, n=3)
* Unidentified sp	*	*	5	Hottentots Bay (07/08, n=2; 08/09, n=3)

*denotes species (or families) that could not be accurately identified

Table 6.5: The energetic contents (kJ/g dry mass) of Southern Mullet specimens collected at Grosse Bucht in southern Namibia. Standard length excludes the caudal fin.

Southern mullet specimen #	Standard length (cm)	Energetic content (kJ/g dry mass)
1	4.7	14.25
2	6.2	14.04
3	–	Sample too small
4	–	15.78
5	7.8	15.32

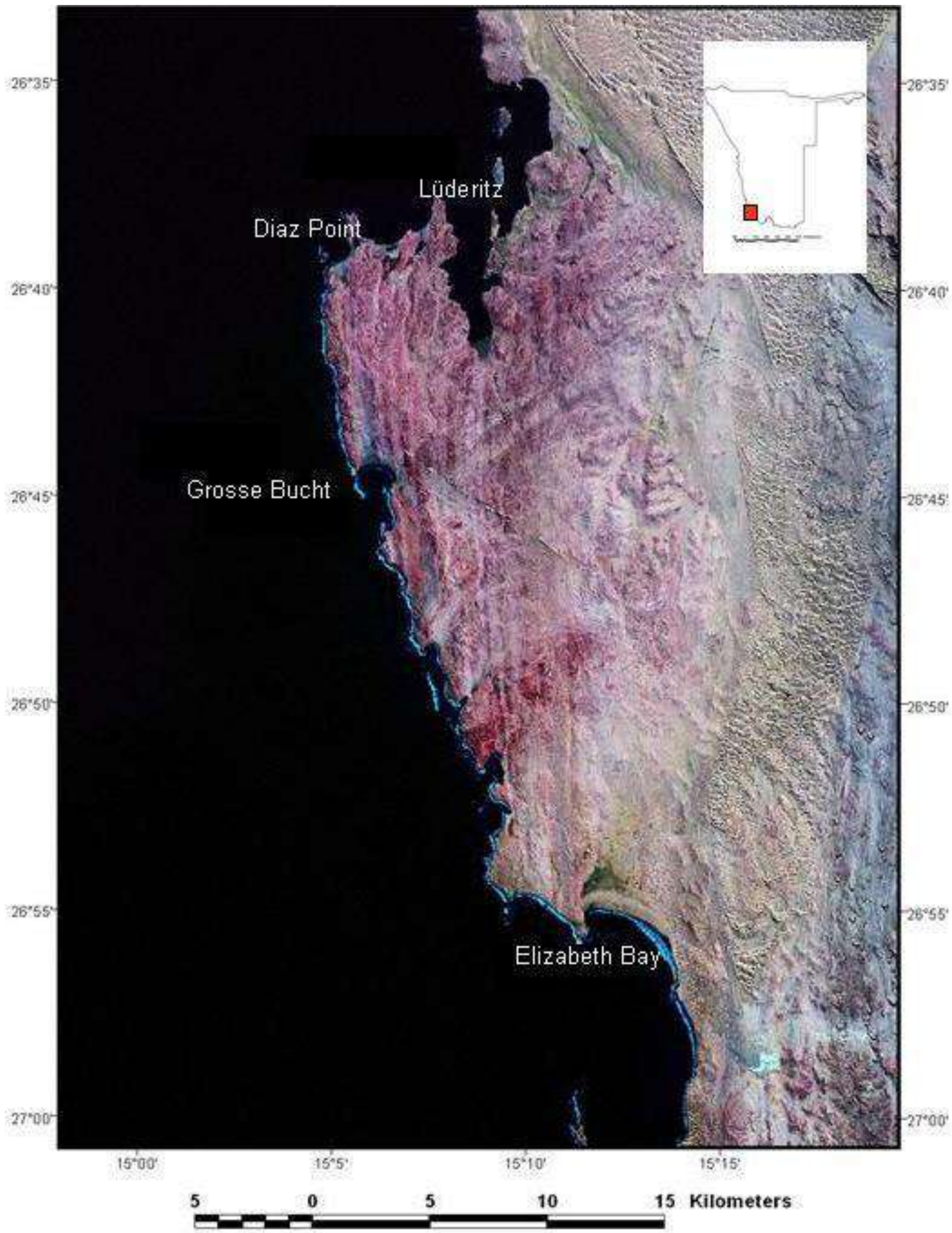


Figure 6.1: Map illustrating Elizabeth Bay and Grosse Bucht in southern Namibia, where the prey capture success of breeding Damara Terns was measured. The map also shows the location of Diaz Point, where wind speeds were measured, and Lüderitz, the nearest town.

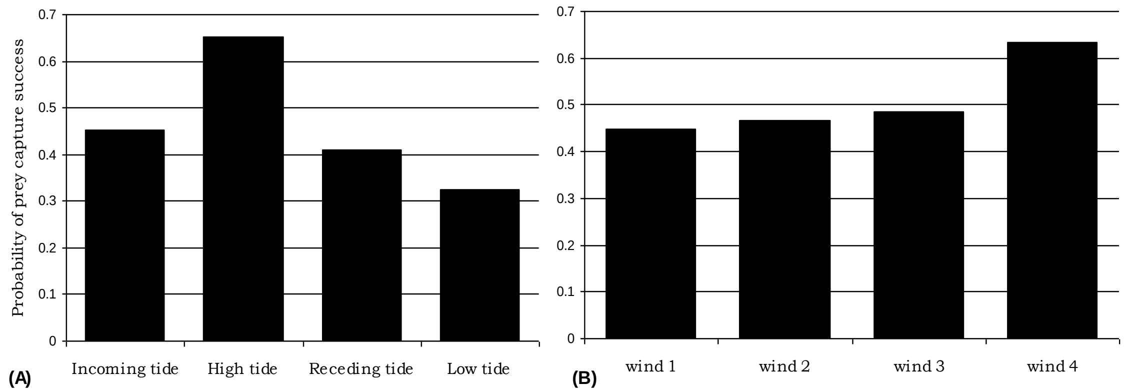


Figure 6.2: Modelled probabilities of prey capture success of Damara Terns in southern Namibia. The probabilities were calculated using the inverse of the logistic transformation from the parameter coefficients of Table 6.1. In each plot, all except one explanatory variable are held constant. Prey capture success probability is shown in relation to (A) tidal phase, with wind set to category 4 and (B) wind speed, with tidal phase set to high tide. The patterns for other combinations of the explanatory variables are similar and therefore not shown.

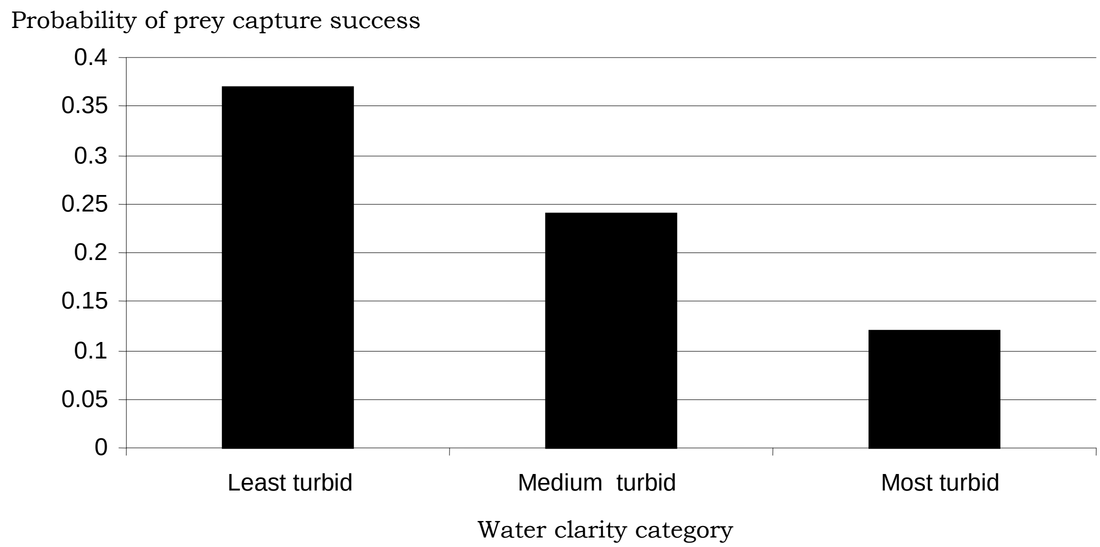


Figure 6.3: Modelled probabilities of prey capture success of Damara Terns at Elizabeth Bay in southern Namibia in relation to water clarity. Water clarity was only measured at Elizabeth Bay, the sample size was thus smaller and the graph and table for water clarity therefore had to be done separately from other analyses (see text). The probabilities were calculated using the inverse of the logistic transformation from the parameter coefficients of Table 6.3. In each plot, all except one explanatory variable are held constant. The plot indicates wind set to category 4 (*c.* 45 km/hr, strong wind) and tide set to high. The pattern for all other combinations of wind categories and tidal phase are similar and therefore not shown.

Chapter 7

The impacts of diamond mining activities on breeding Damara Terns *Sterna balaenarum* in southern Namibia

The impacts of diamond mining activities on breeding Damara Terns *Sterna balaenarum* in southern Namibia

Introduction

Diamond mining along the southern coastline of Namibia is of central importance to the economy of the country (Schneider 2009). Due to the possibility of diamond theft, successive governments of Namibia have restricted access to this area by the public for over a hundred years (Schneider 2009). Consequently, most of the coast between 26°S and 28°S, known as the "Sperrgebiet", has been maintained in almost pristine condition (Pulfrich *et al.* 2003). However, the areas that have been mined have been disturbed extensively.

Terrestrial diamond mining along the Namibian coast principally involves open-cast mining, and requires the removal of overburden, including mobile barchan dunes, before the ore-body can be excavated (Pulfrich *et al.* 2003). At Elizabeth Bay, the undersized grit resulting from the diamond extraction process is deposited as a sediment-slurry directly into the sea, resulting in increased turbidity in the bay (Pallet 1995, Pulfrich *et al.* 2003). Although natural turbidity plumes occurred prior to the operation of the diamond mine, the occurrence and extent of the plumes have increased significantly (Clark *et al.* 1998), and can be seen from the air.

The Damara Tern *Sterna balaenarum*, a breeding near-endemic to Namibia and a Near-threatened species globally (IUCN 2009), has been found breeding in areas of active mining (Connor 1980, Simmons 2005b). Damara Terns breed in loose colonies, with nests rarely less than 100 m apart, on gravel plains and salt pans in the coastal Namib Desert (Simmons and Braine 1994). Both parents provide food for the single chick by carrying single prey items from the foraging areas up to 10 km to the colony (pers. obs). Damara Terns feed mainly by plunge-diving for food (Frost and Shaughnessy 1976, Williams and Myer 1986, Simmons and Braine 1994). Like most of the other small tern species, the Damara Tern is essentially an inshore feeder (McLachlan and Liversidge 1970). Its diet consists of small fish and crustaceans (Clinning 1978, Simmons and Braine 1994, Chapter 6). Due to the nature of foraging, water turbidity may have a significant impact on prey capture success. Most studies on the influence of water turbidity on foraging terns have found that shallow plunge-divers avoid clear waters (Haney and Stone 1988, Safina and Burger 1988), probably because they are more easily detected by their prey. However, Baptist and Leopold (2010) found that prey capture success was lowest in clear and turbid waters. Terns may prefer medium turbidity where they can still see their prey, but aren't as easily detected. Simmons (2005b) postulated that increased turbidity of the water at Elizabeth Bay caused by the discharge of fine sediment negatively affected the foraging success of breeding Damara Terns. If the natural turbidity is anthropogenically enhanced, visibility of prey can be substantially reduced, thus reducing foraging ability of terns accustomed to lower levels of turbidity.

Prey capture success is likely to influence chick condition, breeding success and colony size. Other disturbances resulting from mining (such as dune-stripping, large-scale digging, off-road driving, etc) are also likely to affect success and colony size of breeding Damara Terns at Elizabeth Bay. Because the Damara Tern is to be "Specially Protected" in terms of the draft Protected Areas and Wildlife Management Bill of Namibia and is considered a species of "national conservation importance" (Barnard 1998, Namdeb 2003), the assessment of mining impacts on the survival of this species in the Sperrgebiet has become increasingly important. This chapter investigates the impacts of diamond mining, particularly mining-related sediment discharge, on breeding Damara Terns at Elizabeth Bay. The parameters used to determine these impacts are prey capture success, chick condition (as an indicator of chick provisioning), breeding success and colony size. These parameters obtained at Elizabeth Bay are compared with those obtained from three un-mined breeding localities.

Study Area

The "Sperrgebiet" (restricted diamond area), extends from Hottentots Bay in the north to the southern border of Namibia (see the Sperrgebiet National Park, Figures 1.1 and 1.4 in Chapter 1, Figure 7.1), covering an area of 26000 km^2 and spanning *c.* 320 km of coastline. Four Damara Tern breeding colonies have been found in this area (Figure 1.4 in Chapter 1, Figure 7.1): Hottentots Bay (26°14′S, 14°59′E) in the northern area of the Sperrgebiet; Grosse Bucht (26°43′S, 15°40′E) near the town of Lüderitz; Elizabeth Bay (26°55′S, 15°14′E), an area where diamond mining activities take place; and Marmora Pan (27°45′S, 15°34′E) in the southern area of the Sperrgebiet. The environment of these areas are individually discussed in Chapter 1.

Methods

Foraging observations

Foraging observations were made at Grosse Bucht (control) and Elizabeth Bay (where sediment is discharged). Observations were made throughout the breeding season, during daylight hours, either from a vehicle or from the beach for a period of one to four hours. Foraging Damara Terns were observed using 8×42 binoculars. Foraging bouts were timed to the nearest second and consisted of a tern looking down while flying or hovering 1–5 m above the sea surface. Each successful and unsuccessful dive was recorded per foraging bout. Tidal phase, wind speed, cloud cover and water clarity were recorded during every observation. At Elizabeth Bay, water clarity was recorded at every observation. The methods used to measure these variables are described in Chapter 6. The estimated amount of sediment (range: trickle, medium, full, Plate 4) being pumped by the discharge pipes into the sea at Elizabeth Bay was recorded at every observation.

Monitoring of breeding

In the seasons of 2007/08 and 2008/09, monitoring was undertaken from 1 October to 31 March. Each colony was visited at least once every two weeks and at most once a day. Two people walked separate routes through the general breeding area and searched for new nests by gauging the behaviour of adult birds. Once a nest was found, its coordinates were obtained using a GPS unit, and the site was monitored at each subsequent visit to the breeding area until the egg failed to hatch or hatched successfully. When eggs failed, evidence for the cause of failure was investigated and recorded. Once the chick hatched, the length of the head (0.1 mm), tarsus (0.1 mm) and wing chord (0.1 mm, wing chord for larger chicks was measured using a 30 cm ruler to the nearest 1 mm) were measured and its mass (g) determined with a spring balance shielded from wind. Each chick was fitted with a stainless steel SAFRING ring (2.8 mm internal diameter) on the right leg and a colour ring on the left leg. Attempts were made to find chicks again at every visit until they successfully fledged or died. This proved difficult because chicks are cryptic in plumage and behaviour, and are mobile from their third day (Chapter 3). If chicks were not found their fate was noted as unknown. Observations of chicks found dead or being captured by predators were recorded.

Statistical Analyses

Prey capture success

Prey capture success was defined as the probability of a dive being successful (Chapter 6). A generalized linear model was used to investigate the relationship between prey capture success and a series of explanatory variables. The model used a binomial distribution and a logistic link function (GenStat12 Committee 2009). Five explanatory variables were considered. (1) The "site" was either Grosse Bucht or Elizabeth Bay. (2) Sediment discharge was either occurring or not occurring. During December 2008 and January 2009 no sediment was discharged due to mine closure, allowing a comparison of prey capture success at Elizabeth Bay between months with and without mining-related discharge. Within the season 2008/09, prey capture success was tested using the explanatory variables, "duration of sediment discharge" (October, November 2008 and February 2009), and "duration of no sediment discharge" (December 2008 and January 2009). The detailed descriptions for the remaining three explanatory variables are in Chapter 6: (3) Water clarity, (4) tidal phase, and (5) wind speed.

Body condition index

The body condition index (BCI) of an animal refers to the proportion of its body mass which is available to it in the form of metabolizable energy (Lubbe 2008). Assuming that mass reacts more strongly to variation in food supply than growth of structural components makes it possible to obtain a usable measure of condition by relating the weight of a chick to measures of structural size (Veen *et al.* 2003, 2004). Veen *et al.* (2003, 2004) showed that total head length was the appropriate structural measure for Royal Terns *Sterna maxima* and Caspian Terns *Sterna caspia* and thus I used the same measure for Damara Terns.

The shortcomings of Veen's method, however, were two-fold. Firstly, only an upper curve was fitted to the head length versus mass scatter diagram. Secondly, this upper curve was fitted by eye. Lubbe (2008), in his study of African Penguins *Spheniscus demersus*, overcame the second shortcoming by using quantile regression (Koenker and Bassett 1978, Cade and Noon 2003) to objectively fit the upper curve, finding the 95th percentile regression. Lubbe (2008) further extended Veen's concept by also fitting the 5% percentile regression; this defines the lower limit of normal growth.

He then described BCI of a chick as the proportion of distance between the upper and lower quantiles that a particular chick falls. Lubbe (2008) found that the relationship between head length and mass for African Penguins was linear, and thus his approach was relatively simple. The relationship between total head length and mass for Damara Terns was, however, non-linear. Therefore, a weighted regression model was fitted, using the approach of Underhill et al. (2006). Except, in this case, the 5% and 95% quantile regressions were fitted. This generates two smoothed curves that follow upper and lower boundaries of the scatter diagram closely. The BCI of each chick is defined as

$$(M_o - P_{ML})/(P_{MU} - P_{ML})$$

where *Mo* is the observed mass, and P_{ML} and P_{MU} are the estimated 5% and 95% quantiles of mass, respectively, for a chick of this total head length.

Single-factor ANOVA was used to assess differences in BCI between the four colonies. A two-sample t-test was performed to assess if there were differences between the two seasons.

Breeding success

The breeding success (BS) was defined as the probability of fledging a chick (Chapter 2). Nests (or mobile chicks) were not always found again and evidence of any predation (or other cause of death) was not always available. BS was therefore estimated using the approach developed by Mayfield (1961, 1975) and extended by Underhill (submitted). The detailed statistical methods are described in Chapter 2.

Results

Prey capture success

A total of 389 foraging bouts were observed, of which 177 took place at Elizabeth Bay. The sediment, if being discharged at full power, would affect the entire bay. Damara Terns were always found feeding in the same area – this area was most affected by the plume. Prey capture success did not differ significantly between Damara Terns foraging at Elizabeth Bay and those foraging at Grosse Bucht (P=0.07, Table 7.1). There was also no significant difference in prey capture success at Elizabeth Bay between the duration of sediment discharge (October 2008, November 2008, February 2009) and the duration of no sediment discharge (December 2008 and January 2009) (P=0.888, Table 7.2).

Prey capture success increased significantly with decreasing water turbidity ($P<0.001$, Table 6.3 and Figure 6.3 in Chapter 6). Prey capture success was 0.37 in water clarity 1 (least turbid), 0.24 in water clarity 2, and 0.12 in water clarity 3 (most turbid) (during high tide and calm winds, Figure 6.3 in Chapter 6). Increasing water turbidity always coincided with increasing amounts of sediment being discharged by the pipes into the bay (i.e. trickle= water clarity 1, medium= water clarity 2, full= water clarity 3). Prey capture success increased significantly with increasing tide (Table 6.3 in Chapter 6). Prey capture success was significantly highest during strong winds, and significantly lowest in calm winds (Table 6.3 in Chapter 6).

Chick body condition index

The mean BCI differed significantly between colonies ($F_{3,228}=17.78$, $P<0.001$). Chicks at Hottentots Bay had the lowest mean BCI (0.33, Table 7.3). Those at Elizabeth Bay had the highest mean BCI (0.75, Table 7.3). The mean BCI for chicks from all four colonies combined was significantly higher for 2007/08 than for 2008/09 ($t_{117}=2.56$, $P<0.01$). There was no significant difference in the mean BCI between the two seasons for chicks at Hottentots Bay ($t_{104}=-0.22$, $P>0.05$) and Grosse Bucht ($t_{31}=0.81$, $P>0.05$). Seasonal comparisons could not be made for chicks from Elizabeth Bay and Marmora Pan, because of small sample sizes.

Breeding success (BS) and colony size

Breeding success at all colonies and seasons differed significantly from the baseline of the model (Hottentots Bay 2007/08, Table 2.3 in Chapter 2). Breeding success was significantly higher in 2007/08 than in 2008/09 for three of the four colonies (Table 2.3 in Chapter 2). Decreased BS correlated with increased predation at all colonies (Table 2.4 in Chapter 2).

The number of nests fluctuated between colonies and seasons. Of all four colonies, the number of nests and BS was highest at Hottentots Bay for both seasons (Table 2.3 in Chapter 2). The number of nests at Hottentots Bay was lower in 2007/08 than in 2008/09. Breeding success was significantly higher at Hottentots Bay in 2007/08 than in 2008/09 (2007/08, BS=0.80; 2008/09. BS=0.56; P=0.03, Table 2.3 in Chapter 2). Of all four colonies and for both seasons, predation was lowest at Hottentots Bay (Table 2.4 in Chapter 2).
The lowest BS of all four colonies in 2007/08 was at Grosse Bucht (BS=0.21, Tables 2.3 and 2.4 in Chapter 2). Here, the number of nests was slightly higher in 2007/08 than in 2008/09 (Table 2.3 in Chapter 2). Grosse Bucht had significantly lower BS in 2007/08 than in 2008/09 (2008/09, B=0.48; P<0.001, Table 2.3 in Chapter 2). Predation was higher in 2007/08 than in 2008/09 (Table 2.4 in Chapter 2). Egg abandonment at Grosse Bucht was higher in 2008/09 than in 2007/08 (Table 2.4 in Chapter 2).

Of the four colonies, Elizabeth Bay had the lowest number of nests during both seasons (Table 2.3 in Chapter 2). Elizabeth Bay and Marmora Pan had equally the lowest BS of all colonies in 2008/09 (Tables 2.3 and 2.4 in Chapter 2). The number of nests at Elizabeth Bay decreased from 13 in 2007/08 to 4 in 2008/09 (Table 2.3 in Chapter 2). BS was significantly higher in 2007/08 than in 2008/09 at Elizabeth Bay (2007/08, BS=0.24; 2008/09, BS=0.09; P=0.001; Table 2.3 in Chapter 2). Predation was high during both seasons at Elizabeth Bay (Table 2.4 in Chapter 2).

The number of nests at Marmora Pan decreased from 55 in 2007/08 to 13 in 2008/09 (Table 2.3 in Chapter 2). BS at Marmora Pan decreased significantly from 0.25 in 2007/08 to 0.08 in 2008/09 (P>0.001, Table 2.3 in Chapter 2). Of all colonies and for both seasons, predation was highest at Marmora Pan.

Discussion

Mining-related sediment discharge was not found to significantly affect prey capture success of Damara Terns breeding at Elizabeth Bay. However, prey capture success was highest in least turbid waters (and at high tide and strong wind, Chapter 6). Chick condition was highest at Elizabeth Bay, and lowest at Hottentots Bay. Chick condition was significantly higher in 2007/08 than in 2008/09 for all colonies combined. Breeding success and the number of nests were highest at Hottentots Bay for both seasons. Breeding success was mainly affected by predation.

Prey capture success

Prey capture success did not differ significantly between Grosse Bucht and Elizabeth Bay, and no significant difference in prey capture success was observed at Elizabeth Bay during months of sediment discharge and months of no sediment discharge. Therefore it is unlikely that foraging Damara Terns at Elizabeth Bay were negatively affected by sediment discharge. However, Damara Terns dived more successfully in less turbid waters, during lowered sediment discharge rates.

Previous studies have shown that shallow plunge-divers generally prefer more turbid water (Haney and Stone 1988). The greatest upwelling cell in the Benguela Upwelling System is located near Lüderitz and surrounding areas (Shannon 1989). Water turbidity is therefore naturally high at both Elizabeth Bay and Grosse Bucht (Clark *et al.* 1998); both are in the vicinity of Lüderitz. Some turbidity may be preferred by plunge-divers because prey may concentrate in the upper layers. In addition, plunge-divers may also not be as easily detected by their prey in more turbid waters. Damara Terns breeding and foraging in these areas may be accustomed to foraging in relatively turbid waters and therefore are not greatly affected by increased turbidity generated by mining activities. A study of fish communities (especially fish that Damara Terns prey on) in Elizabeth Bay showed that elevated turbidity levels have a positive impact on fish communities in the bay (Clark *et al.* 1998). A higher abundance and diversity of fish species were found in the sediment plume at Elizabeth Bay, and the turbidity plume resulting from the fine tailings disposal may have enhanced the quality of the Elizabeth Bay surf zone as a habitat for juvenile fish (Clark *et al.* 1998). In this sense the increased turbidity may have had a positive impact.

Because Damara Terns showed higher prey capture success in the least turbid waters, during lowered sediment discharge rates, there seems to be some effect of discharging sediment on foraging Damara Terns at Elizabeth Bay. Unfortunately, no total suspended matter (TSM) concentration data, to illustrate turbidity more accurately, were available for this study. Least turbid water at Elizabeth Bay is turbid relative to what is considered clear water (i.e. the clearest water at Elizabeth Bay was *c.* 5 mg/l, measured between 1995–1997, during sediment discharge rates comparable to present discharge rates, CSIR 1996, 1997, 1998). Baptist and Leopold (2010) found that Sandwich Terns had highest prey capture success in water with TSM concentration of 5–10 mg/l. This measurement is within range of the least turbid water in my study. I postulate that my results reflect a linear response to turbidity because the water at Elizabeth Bay probably did not include turbidities that had TSM concentration lower than 5 mg/l.

Chick body condition

The body condition of seabird chicks (such as terns) is directly related to the amount of food they get from their parents, which can be related to feeding conditions at sea (Williams and Croxall 1990, Veen *et al.* 2003, 2004). Generally, it seems that Damara Tern chicks seldom die of starvation (Figure 7.2). Chicks at Hottentots Bay had the lowest mean BCI. Compared to the other colonies, Hottentots Bay had the largest distance between nest sites and foraging grounds. Therefore breeding Damara Terns may feed their chicks less frequently because more time is spent traveling to and from foraging grounds. However, the highest mean BCI was of chicks from Elizabeth Bay, where nest sites are also relatively far from foraging grounds. Insufficient data was available to assess whether chick provisioning was affected by distance. The energy content of prey caught may have differed between colonies, but no data was available to make such comparisons.

Breeding success and colony size

Hottentots Bay had the highest breeding success, because of a lower rate of predation than at the other sites. This is likely to be due both to the size and isolation of the breeding area and to the substrate which rendered eggs and chicks particularly difficult to detect there (Plates 1 and 5). At Marmora Pan, where predation was highest, incubating adults (and eggs) are not cryptic and generally easily detected (Plates 1 and 5). The higher breeding success at Grosse Bucht in 2008/09 may be attributed to a lower rate of predation. Breeding success was mainly affected by predation at all colonies. My results showed no direct impact of mining activities on breeding success at Elizabeth Bay. In fact, the nearest mining activities (i.e. dune stripping), occurred *c.* 1.5 km from the nesting grounds. Breeding success was also not negatively affected by the sediment discharge.

The breeding colony at Elizabeth Bay was the smallest of the four colonies considered here, despite the availability of large areas of suitable breeding habitat. Frost and Johnson (1977), Siegfried and Johnson (1978) and Johnson (1979) surveyed Elizabeth Bay in three consecutive years (1976, 1977, 1978) and estimated a maximum of 20 breeding pairs, but never found more than 13 nests. The colony size of 13 nests in 2007/08 is comparable with this estimate. There may have been a decline in breeding pairs there since mining began in 1991. However, the use of different census methods makes comparisons of population estimates and interpretation of apparent population trends difficult (Chapter 9). The decrease in the number of nests between the 2007/08 (n=13) and 2008/09 seasons (n=4) at Elizabeth Bay is likely to have been a function of food availability at all southern Namibian breeding localities rather than the effects of diamond mining, particularly because mining activities were greatly reduced during 2008/09 (because of the financial crisis, Babatunde 2009, Congleton 2009). Many terns may have decided not to breed at all during 2008/09 as a result of poor conditions. The decrease in nest numbers from the 2007/08 season to the 2008/09 season and the poor chick condition were indicative of the season 2008/09 being a poor breeding season. Poor feeding conditions usually result in small nest numbers (i.e. a substantial proportion of birds electing not to attemp to breed) and poor breeding success in terns (Nisbet 1978, Monaghan *et al.* 1989, Chapter 2). The increased number of nests at Hottentots Bay between the 2007/08 and 2008/09 seasons reflects a greater search effort for nests in the latter season and it is possible that the number of nests at Hottentots Bay was higher in 2007/08 than in 2008/09 (search effort was doubled from 2007/08 to 2008/09, Chapter 2).

This study found that, although prey capture success of Damara Terns at Elizabeth Bay was lower during increased sediment discharge rates, sediment discharge had no negative effect on the overall prey capture success, chick condition, breeding success or colony size compared with that of three un-mined colonies. However, the higher prey capture success of feeding Damara Terns in least turbid waters at Elizabeth Bay indicates that sediment discharge levels should not reach levels of undesirable turbidity. Further studies should measure TSM concentrations during foraging to assess more accurate levels of turbidity during foraging observations. An investigation into the comparison of chick provisioning rates and energy content of prey at the four colonies may explain why the BCI differed between colonies.

Table 7.1: Results of the generalized linear model for prey capture success of Damara Terns in southern Namibia with "site" as a two-level explanatory variable, i.e. Grosse Bucht versus Elizabeth Bay (the baseline level of the model).

Explanatory variable	Coefficient	SE	$t_{388,2}$	P-value
Constant	–1.157	0.346	–3.35	<0.001
Elizabeth Bay	0	0	0	–
Grosse Bucht	0.778	0.429	1.81	0.070

Table 7.2: Results of the generalized linear model for prey capture success of Damara Terns at Elizabeth Bay with explanatory variable "sediment discharge". "Months with no sediment discharge" is set as the baseline level of the model.

Explanatory variable	Coefficient	SE	$t_{79,2}$	P-value
Constant	–0.693	0.236	–2.94	0.003
Months with no sediment discharge	0	0	0	–
Months with sediment discharge	–0.042	0.295	–0.14	0.888

Table 7.3: The Body Condition Index of Damara Tern chicks at four colonies in southern Namibia. Each entry in the table is mean Body Condition Index (standard deviation), sample size.

Colony	2007/08	2008/09	Both seasons
Hottentots Bay	0.32 (0.24), 26	0.34 (0.32), 82	0.33 (0.33), 108
Grosse Bucht	0.66 (0.22), 16	0.48 (0.27), 19	0.55 (0.30), 45
Elizabeth Bay	0.77 (0.31), 20	0.63 (0.31), 2	0.75 (0.31), 22
Marmora Pan	0.60 (0.33), 53	0.00 (–), 1	0.59 (0.28), 54

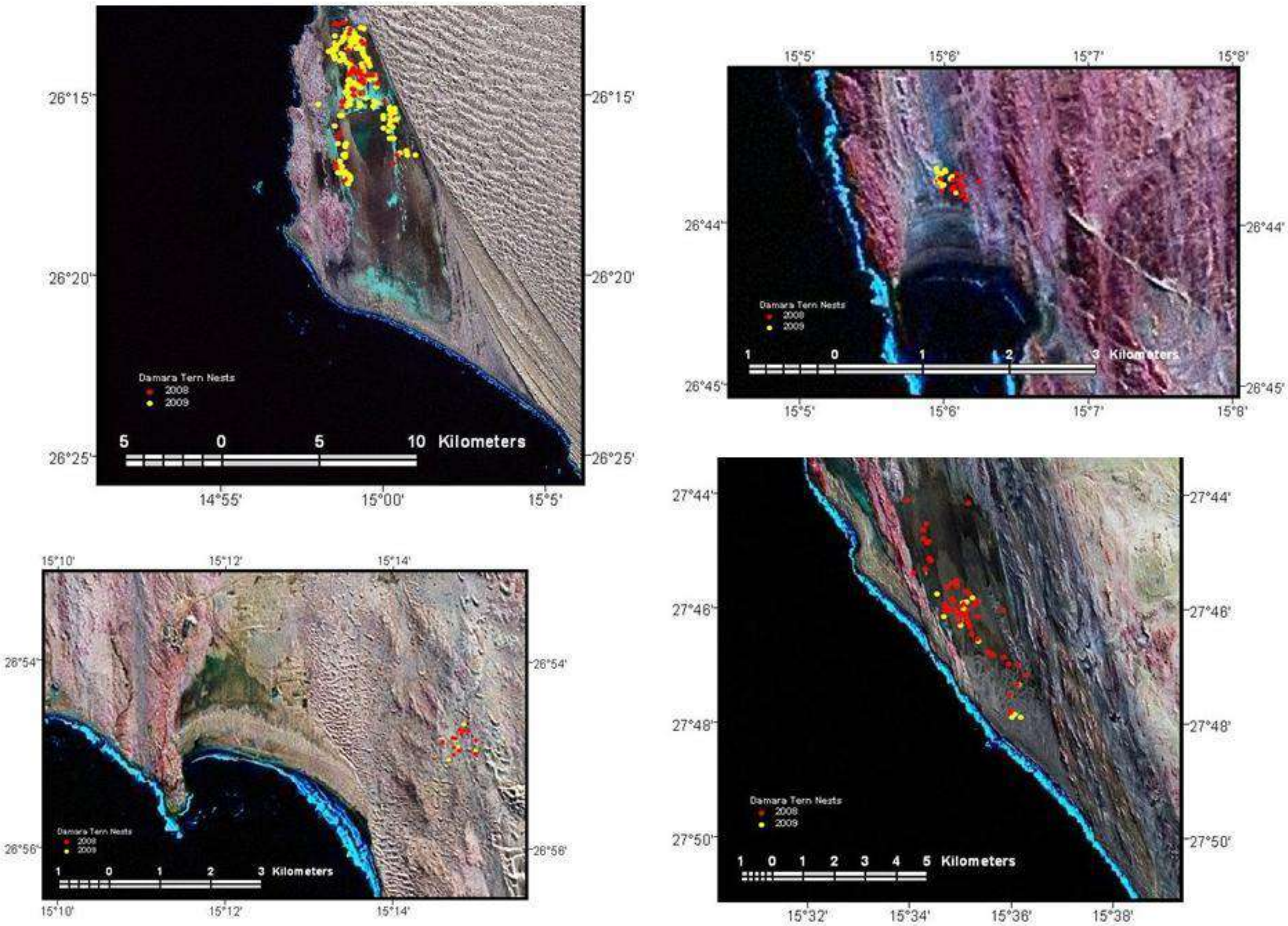


Figure 7.1: Satellite images of the location of colonies of Damara Terns in southern Namibia: Hottentots Bay (top left), Grosse Bucht (top right), Elizabeth Bay (bottom left) and Marmora Pan (bottom right). Nest distributions during 2007/08 are shown in red and 2008/09 in yellow.

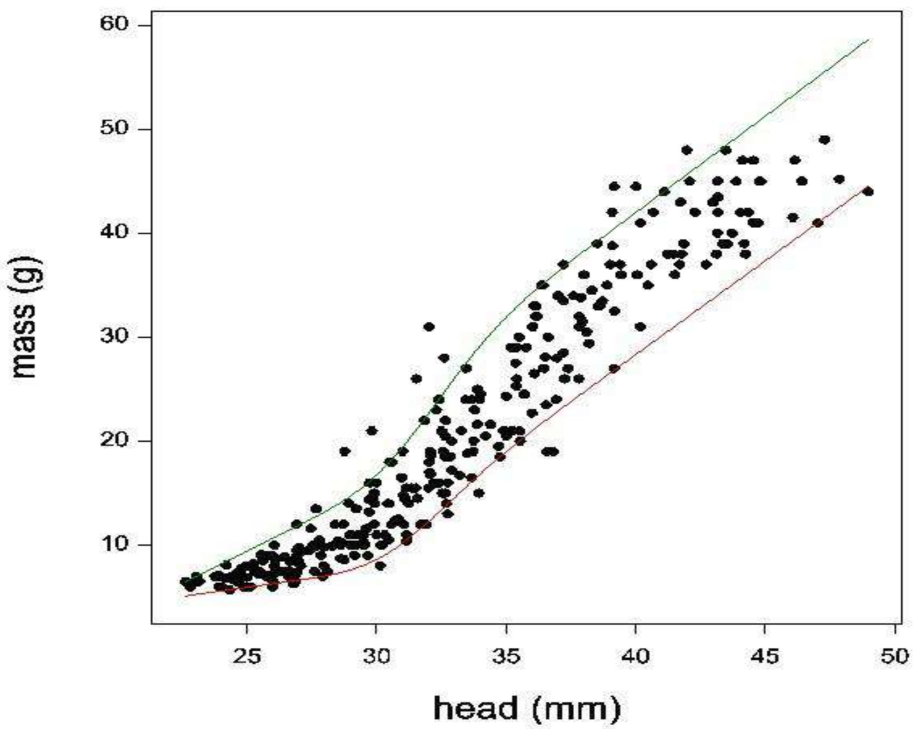


Figure 7.2: Body condition of Damara Tern chicks at four colonies in southern Namibia as measured by total body mass versus head length. The upper line is the 95th percentile, the lower line is the 5th percentile (see text).

Chapter 8

Protecting Damara Terns *Sterna balaenarum* from recreational disturbance in the Namib Desert increases breeding density and overall success

Sigi Braby

Protecting Damara Terns *Sterna balaenarum* from recreational disturbance in the Namib Desert increases breeding density and overall success

Introduction

The Damara Tern *Sterna balaenarum*, one of the smallest members of the Sternidae, is a breeding near-endemic to Namibia. Only 2% of the global population breed outside the country, along the coastlines of Angola and South Africa (Crawford and Simmons 1997). The strip of coastline between Swakopmund and Walvis Bay, two coastal towns in central Namibia *c.* 40 km apart, has the greatest density of sea- and shorebirds roosting and feeding in southern Africa (Simmons *et al.* 1998b). The Damara Tern nests adjacent to this strip, on the gravel plains that run parallel to the coast (Simmons *et al.* 1998b, Braby *et al.* 2001, Simmons 2005a).

The Damara Tern typically lays one egg in a nondescript scrape on the ground, although two-egg clutches have been recorded on rare occasions (de Villiers and Simmons 1997, Chapter 2). Unlike other terns, Damara Terns breed in loose colonies with an average density of 1–8 nests per km^2 (Crawford and Simmons 1997). Damara Terns are mainland coastal breeders and prefer non-vegetated gravel or sandy plains and saltpans (Simmons 2005a). They often breed up to 5 km inland, with one record breeding as far as 11.5 km inland (Braby *et al.* 2001). The main breeding season starts in September and ends in April, but nests with eggs occur as late as June (Simmons and Braine 1994) indicating that breeding can extend over nine months. During the non-breeding period Damara Terns migrate to West Africa (Elgood *et al.* 1973, Braby 2010).

Three decades ago, the Damara Tern was listed as one of the 20 bird species breeding in South Africa most in need of conservation action (Siegfried *et al.* 1976). Subsequently, its global threat status has varied between Globally Threatened to Near-threatened (IUCN 2009).

Breeding Damara Terns are particularly vulnerable to human disturbance and conservation measures have been implemented to ensure their continued survival. Human disturbance in the Namib Desert is associated with recreational activities such as off-road vehicles (ORVs), quad-bikes, horse-riding and hiking. The densest population of breeding terns is found on the central Namibian coast during the austral summer, at the same time as the number of visitors to the area is greatest. Damara Terns have been subjected to excessive disturbance and increased mortality during the breeding season in this area owing to off-road driving and quad-bike activity (Braby *et al.* 2001).

During November 2000, cable barriers were erected at a Damara Tern breeding colony at Caution Reef to prevent ORVs from traveling across the sand and gravel plains where terns bred (Braby *et al.* 2001). However, it subsequently became apparent that large numbers of Damara Terns were breeding east of Caution Reef (Braby 1995) in an area known as Horses Graves. Here terns were found breeding in gravel plains situated between dunes in an area popular with quad-bikers.

To determine the effectiveness of conservation measures, and to compare their success with that at the Caution Reef colony (Braby *et al.* 2001), the Horses Graves colony was monitored during the 2001/02 breeding season, when it was subjected to a high level of quad-bike traffic. The colony was again monitored during the following breeding season (2002/03) after interpretive sign board had been erected and strict access restrictions had been enforced. This chapter compares Damara Tern nest numbers and densities, breeding success, and causes of mortalities before and after these measures were implemented.

Methods

The study was conducted between September and March over two breeding seasons, 2001/02 and 2002/03. I searched the study area on a quad-bike and recorded Damara Tern eggs and chicks and all vehicles or new tracks crossing the area. These searches were done daily; time of day varied from early in the morning to late in the afternoon. A record was kept of the date, time and location of all tracks and vehicles in the study area in December 2001. One route was followed through the study area to monitor breeding activities, but on occasion I explored new plains in search of potential nesting sites. A Global Positioning System (GPS) was used to record the exact location of each nest to an accuracy of *c.* 10 m. New nests were included into daily visit routines until the chick successfully hatched and was ringed or until nest failure. Breeding success was defined as the emergence and survival of a chick that moved away from its nest aged 3–4 days – a combination of hatch success and early survival. Thereafter I could not easily follow the cryptic chicks and be certain that they had perished if they were not subsequently found. The presence of potential predators such as Kelp Gulls *Larus dominicanus*, Rock Kestrels *Falco rupicolus* and Black-backed Jackals *Canis mesomelas* was recorded and failed nests were carefully examined for signs of predators, such as jackal tracks leading to empty nests. When known, the cause of nest failure was noted.

Information and interpretation sign boards were erected on 21 December 2001, in the middle of the breeding season 2001/02. Signs of human disturbance continued to be monitored. Prior to the start of the 2002/03 breeding season, cable barriers were set up at entry points to the study area that were typically used by quad-bikes (Plate 3). Quad-bike tour companies were limited to one designated route and private bike enthusiasts were warned off the gravel plain areas. Information sheets highlighting the vulnerability of Damara Terns and the position of the breeding site were handed out to private quad-bikers and other tourists.

Results

Nest abundance and density

All nests found over the study period contained one egg. In the 2001/02 breeding season, the first nest was found on 2 November and, in total, 58 nests with eggs were found over a period of two and a half months (Figure 8.1). The breeding season ended on 23 January 2002, with no more eggs or chicks seen after this date. During the 2002/03 breeding season, 122 nests with eggs were found over a four-month period, with the first egg appearing on 24 October 2002 and breeding activity recorded until 23 February 2003 (Figure 8.2). Field work occurred before these dates and until March to ensure no further egg-laying. Nest abundance more than doubled from the 2001/02 season to the 2002/03 season. The density of nests in the 2.5 km^2 study area increased from 23 nests km^{-2} in 2001/02 to 49 nests km^{-2} in 2002/03 indicating a 2.1-fold increase in breeding density following reduction in disturbance to the area. A possibility exists that nest density was larger in 2002/03 because of the longer season. I controlled for this by examining the same two-and-a-half month period (2 November to 23 January) in both seasons, when the relative densities were 23 nests km^{-2} in 2001/02 and 34 nests km^{-2} in 2002/03 indicating a 1.5-fold increase. There was no increase in the area occupied by the terns. Assuming that each nest represented a different breeding pair, the number of nests in 2002/03 was significantly larger than in 2001/02 (comparison of two counts, z=4.78, P<0.001; Zar 1999). There were, in fact, at most 15 pairs that re-laid in 2002/03, so that at least 107 pairs bred that year. The breeding population was significantly larger in 2002/03 than in 2001/02 ($z=3.81$, $P<0.001$).

Human disturbance

In the 2001/02 season, new vehicle tracks were seen on a daily basis and sometimes more frequently. Vehicles were common on both the gravel plains and the dunes. Quad-bike tracks were most common. In November 2001, nine ORVs were observed driving through the study area at the start of the breeding season. During December 2001, 27 new sets of quad-bike tracks, five ORVs or their tracks and one set of horse tracks (which passed within two metres of an active nest) were encountered during a 30-day period. About 30% of the quad-bike tracks were multiple tracks made by up to seven quad-bikes at a time. Tracks frequently passed within metres of nests with eggs, indicating that the bikers were unaware or uninterested in the tern nests. In six cases, vehicle tracks were found within 5 m of an active nest, but no nests were destroyed by vehicles. There was no apparent decrease in vehicle disturbance after conspicuously placed information boards were erected along all borders of the study area on 21 December 2001.

During the 2002/03 season, after additional conservation measures had been implemented, quad-bike tours were only seen following routes allocated to them. With one exception, tourists in ORVs drove only in dunes and always at safe distances from the nests. Only human or horse tracks were found in the vicinity of nests. There were no quad-bike tracks through the nesting area. Human disturbance was only witnessed on two occasions: two tourists walking through the gravel plains and an ORV driving through one breeding plain where a small number of Damara Terns nested.

Breeding attempts and overall breeding success

The number of successful breeding attempts increased from 48 nests in 2001/02 to 82 nests in 2002/03, a 71% increase (Table 8.1). However, as a percentage of nests initiated, successful nests decreased significantly from 83% (48 of 58) in 2001/02 to 67% (82 of 122) in 2002/03 (χ^2_1=4.1, P=0.043, Table 8.1; see Chapter 2 for the probability of breeding success to fledging, 0.73 for 2001/02 and 0.52 for 2002/03). Despite the significant decrease in the proportion of nests successful before and after protection, the increased number of nests in the second year resulted in 34 more chicks surviving until 4 d of age following the implementation of protective measures.

The reduced proportion of successful nests in 2002/03 was attributable to predation by Black-Backed Jackals, as determined by tracks at failed nests (Table 8.1, Chapter 2). The number of nests failing from jackal predation increased four-fold from five nests in 2001/02 to 20 nests in 2002/03 (Table 8.1). In addition, a Rock Kestrel was periodically seen flying over the area during the 2002/03 breeding season; this species had not been observed during the previous season. A pair of Rock Kestrels was known to have bred in the vicinity of the study area in 2002/03. Subsequently, in 2005, a Rock Kestrel was observed predating a Damara Tern chick (Chapter 2). It is thus likely that a substantial proportion of the losses attributed to 'unknown fate' (Table 8.1) involved predation by Rock Kestrels. Nest abandonment due to direct human disturbance decreased from two nests (3%) in 2001/02 to one nest (0.8%) in 2002/03 (Table 8.1).

Discussion

My results show that conservation interventions can be audited, and their benefits quantified, by measuring a number of biological parameters, such as breeding numbers, density and success of breeding, as well as intensity of disturbance before and after the implementation of the interventions. In this study, there was a large increase in the number of Damara Terns breeding in the season following the exclusion of ORVs from the breeding area and the limitation of quad-bikes to fixed routes through it. Similarly, Braby *et al.* (2001) showed that nest density increased by 25% and that hatching success increased from 56% to 80% at the Caution Reef colony in the breeding season following exclusion of ORVs. At the southern limit of the species' breeding range, near Cape Agulhas, South Africa, all 11 pairs in the study area raised a chick to fledging in the year immediately following the ban on ORVs from beaches in South Africa (Williams *et al.* 2004). In the previous five years many pairs lost eggs or chicks during the midsummer holiday period due to disturbance attributable to ORVs. The similar results obtained in each of these three studies suggest that the protective measures played an important role in improving breeding participation and success. Non-breeding coastal seabirds also increased in number in study areas around the South African coast following the ban on ORVs (Williams *et al.* 2004).

In this study, once conservation measures were implemented, the breeding season lengthened from two-and-a-half to four months. There may be several reasons for the lengthening of the breeding season. Increased food resources to adults and chicks, known to be critical in tern breeding ecology (Nisbet 1978, Monaghan *et al.* 1989), could account for this change. At both Struisbay and in this study, the breeding season started earlier after disturbance was eliminated, so that protection may have contributed to the lengthening of the season. Breeding earlier provides fledglings with a longer period of preparation for migration (Williams *et al.* 2004).

Once vehicle disturbance was eliminated, it was found that predation was an unexpected determinant of breeding success. The reduced breeding success in the second year was attributable to increased levels of predation by jackals, and probably by the arrival of a new predator, the Rock Kestrel (Chapter 2). Ecological factors such as these could not have been addressed through these conservation measures, but in hindsight may be expected for a ground-nesting species reliant on cryptic, well-spaced nests. Predation levels can increase naturally as nest density increases (Newton 1998), so it is useful to examine how much higher these densities were than typically encountered on the Namibian coast.

Nest densities in both seasons (23–49 nests km^{-2}) were higher then previously recorded along Namibia's coast (1–15 nests km^{-2}, Simmons *et al.* 1998a) and at nearby Caution Reef colony (12–15 nests km^{-2}, Braby *et al.* 2001). The high densities at Horses Graves cannot be attributed to breeding habitat limitation, as there are vast areas of gravel plains available, nor can it be an anti-predator strategy as predation increases with higher tern densities.

Measuring the effectiveness of conservation measures is an essential but often untested step in the protection of any threatened biome, habitat or species. Managers should not simply assume that conservation efforts will be successful or that testing the effectiveness of measures is unnecessary, even if managers fear that this will reveal that resources used and expenses incurred were not justified. I recommend that funders of conservation projects set aside a portion of the funding for auditing the effectiveness of conservation interventions. In this case I demonstrated that the conservation measures enacted were effective, a result consistent with observations at two other sites in Namibia and South Africa.

Table 8.1: The outcomes of Damara Tern breeding attempts during the 2001/02 and 2002/03 breeding seasons at the Horses Graves, central Namibia

Fate	**2001/02**	**2002/03**
Jackal Predation	5 (8.6%)	20 (16.4%)
Egg addled	0 (0%)	2 (1.6%)
Chick found dead	0 (0%)	2 (1.6%)
Egg Abandoned	2 (3.4%)	1 (0.8%)
Unknown Fate*	3 (5.2%)	15 (12.3%)
Successful	48 (82.8%)	82 (67.2%)
Total nests with eggs	**58**	**122**

* 'Unknown fate' is defined by an egg or chick that was not found again but the cause of disappearance was unknown.

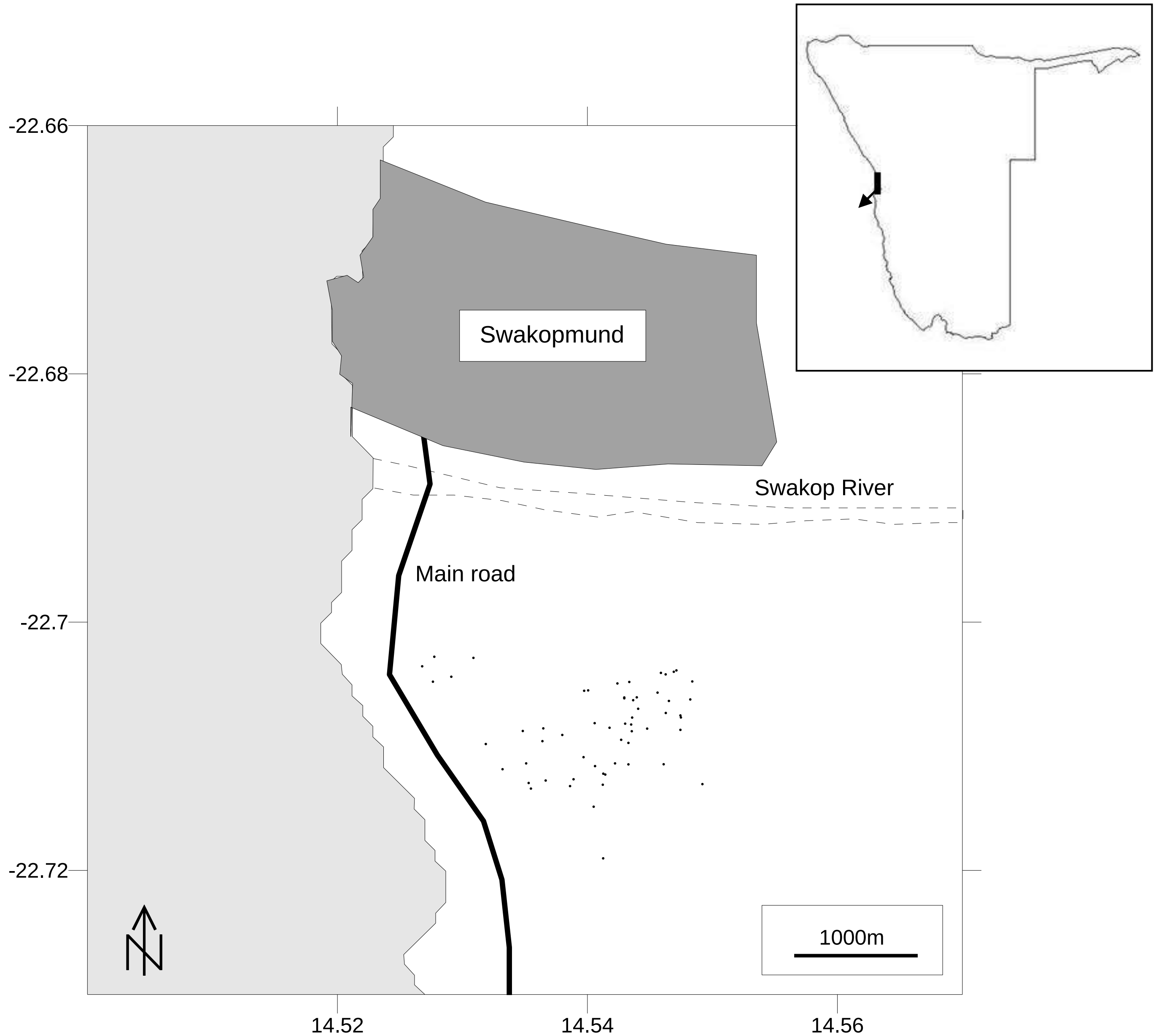


Figure 8.1: Damara Tern nesting distribution during the 2001/02 breeding season at Horses Graves, central Namibia, before the colony was fenced.

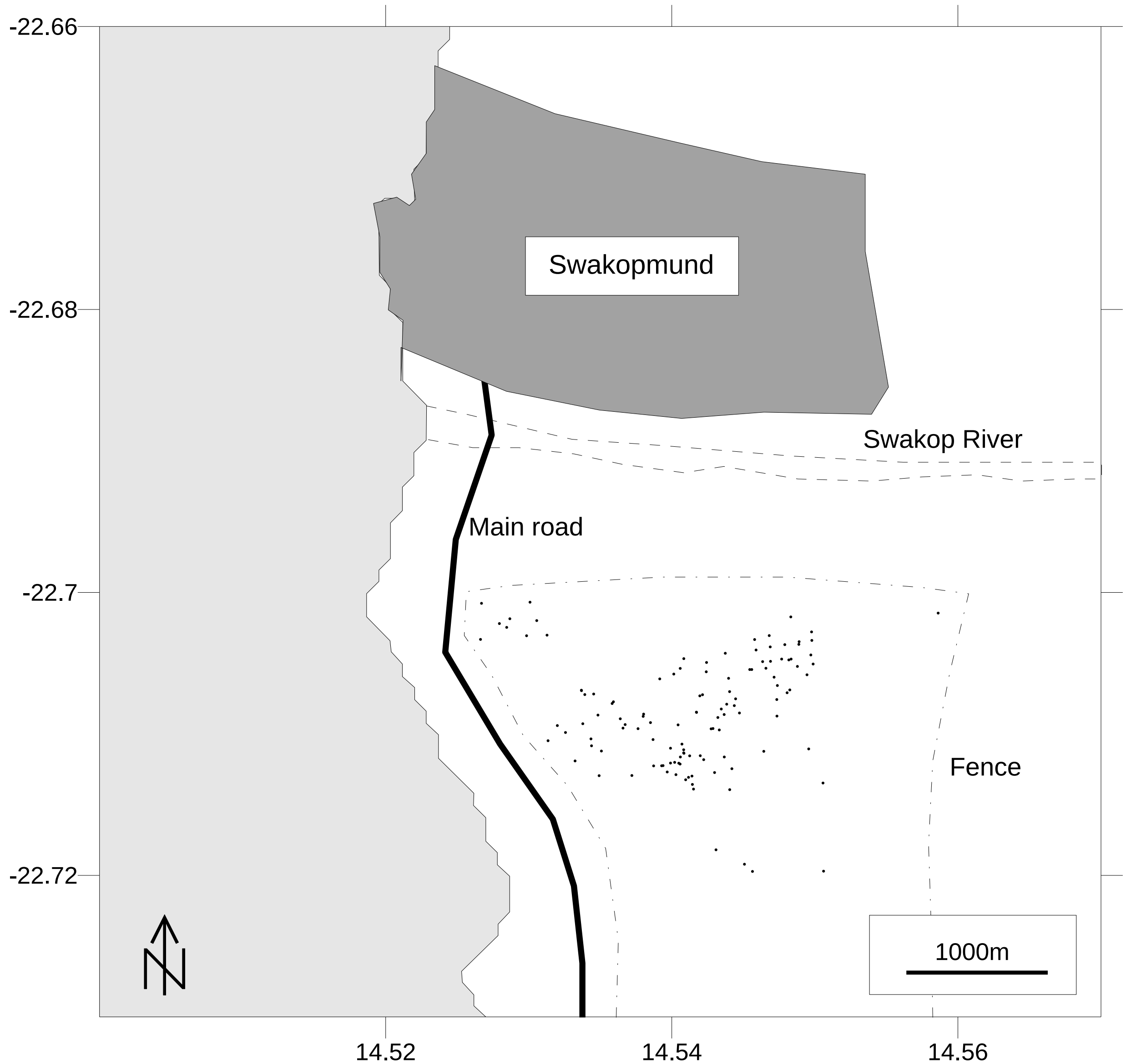


Figure 8.2: Damara Tern nest distribution during the 2002/03 breeding season at Horses Graves, central Namibia, after the colony was fenced.

Chapter 9

Population estimates, distribution and conservation of the Damara Tern *Sterna balaenarum*

Population estimates, distribution and conservation of the Damara Tern

Introduction

The globally Near-threatened Damara Tern *Sterna balaenarum* is known to breed in three countries, from the northern Namib Desert in southern Angola (S16°58′, E11°46′), through Namibia, to the Eastern Cape in South Africa (S33°30′, E25°48′) (Every 1979, Underhill *et al.* 1980, Randall and McLachlan 1982, Watson 1998, Simmons 2005a, 2010). Recent estimates of the global breeding population vary widely (Simmons *et al.* 1998a, Kemper *et al.* 2007), largely due to the use of various census methods and a lack of information on breeding population size throughout the species' range.

Little is known about the number of breeding individuals in Angola, and breeding was first confirmed there in 2010 (Simmons 2010). According to Crawford and Simmons (1997), 98% of Damara Terns breed in Namibia. This is probably due to its central position along the highly productive Benguela Upwelling System (Shannon 1985, 1989, Sakko 1998) that provides ample food, as well as the availability of extensive and isolated breeding habitat in the Namib Desert (Simmons *et al.* 1998a, Braby *et al.* 2001). Numbers of breeding pairs in South Africa are small and declining, and the species is classified as nationally Endangered (Barnes 2000).

The two most recent estimates of the total number of breeding Damara Terns varied widely, and taken at face value, suggest a severe decline in the breeding population from an estimated 13 500 breeding individuals in 1998 (Simmons *et al.* 1998a) to 930 pairs in 2007 (Kemper *et al.* 2007). This uncertain information suggests that a revision of breeding population estimates is timely. This chapter collates and reviews the published and unpublished information of counts of individual birds, nest counts and locations of breeding colonies and provides revised population estimates. Threats faced by a number of breeding colonies are discussed, the conservation measures that have been put in place to protect breeding colonies are detailed, and other ways to protect the major breeding colonies of Damara Terns are suggested.

Study area and methods

This review included information from Tombua, *c.* 200 km north of the Cunene River in Angola (15°47'S, 12°09'E), to the Alexandria Dune Fields east of the Sundays River (22°42′S, 25°55′E) in South Africa, and included all known breeding areas within this *c.* 3500 km stretch of coastline (Figure 9.1). In Angola, breeding terns are found on gravel plains (Simmons 2010). In Namibia, breeding terns are found on an array of habitats including saltpans, sand and gravel plains, and gravel slacks between barchan dunes (Frost and Shaughnessy 1976, Clinning 1978, Simmons and Braine 1994, Simmons *et al.* 1998a). For the purpose of this study, Namibia was divided into four regions: Skeleton Coast Park (SCP); Dorob National Park (DNP); Namib-Naukluft Park (NNP); and Sperrgebiet National Park (SNP) (Figures 1.1–1.5 in Chapter 1) . These areas are described in detail in Chapter 1. In South Africa, breeding areas are mainly confined to dune fields where Damara Terns breed in the slacks between the dunes; however, some are found on saltpans, such as the small breeding colony at Port Nolloth, Northern Cape (29°14′S, 16°52′E), and gravel mounds, such as the breeding areas around Alexander Bay, Northern Cape (28°35′S, 14°38′E).

A "colony" is defined as a distinctive area of breeding habitat of Damara Terns to which breeding pair(s) return each year to breed. Data used to assess breeding populations were collected using three different methods, namely:

1. Long-term monitoring, where colonies were monitored (at daily to weekly intervals) over three breeding seasons or more.
2. Short-term monitoring, where colonies were monitored (at daily to weekly intervals) for a minimum of two months to a maximum of one full breeding season (up to six months).
3. Short surveys/anecdotal nest records, where short (duration of a minimum of one day to a maximum of one week) surveys were conducted at colonies and where nests with eggs, chicks, adult and fledged Damara Terns were counted during the visit. In some cases, surveys were conducted more than once over the breeding season or over several breeding seasons.

The number of breeding pairs at each known colony was estimated. Minimum and maximum estimates are reported to account for possible fluctuations in numbers of pairs breeding between years, and to accommodate uncertainties associated with different census methods. Minimum estimates were based on minimum nest counts, irrespective of the survey method. Maximum estimates were based on maximum nest counts for long-term monitored colonies (section 3 above, however, e.g. Hottentots Bay was estimated based on breeding pair number because only a third of the area was surveyed for nests). Maximum estimates for the colonies for which short-term survey (section 3 above) information was available were estimated individually for each colony based on the following factors:

- The size of available/potential breeding habitat
- The level of disturbance (predators and human)
- Available notes on counts and behaviour of breeding adults
- The timing of the survey

Due to the vast expanse of available habitat in the Namib Desert, some pairs breed solitarily and sporadically outside of colonies (hereafter referred to as "single pairs") along the Namibian coastline (Simmons *et al.* 1998a). The occurrence of single pairs in South Africa is unlikely, because of the restricted availability of suitable breeding habitat there. No records of these exist in Angola or South Africa. Records of single pairs along the Namibian coastline were incorporated into the overall breeding population estimate. This information was derived from surveys of breeding habitat in the SNP (January 2007–April 2007, October 2007–April 2008, October 2008–April 2009, J. Braby unpubl. data), estimates given by Braby *et al.* (2001) for the area between Meob Bay and Hottentots Bay, sporadic nests found between colonies in the DNP north of Swakopmund (December 2009–February 2010; J. Braby unpubl. data) and the entire SCP and DNP (1983–1998; MET unpubl. data).

Results

A total of 70 known breeding colonies were found to exist in Angola, Namibia and South Africa (Tables 9.1 and 9.2, Figure 9.1). Of these, eight colonies have been subjected to long-term monitoring, 20 colonies were monitored over short-terms and 42 colonies were monitored through short surveys or were anecdotal records (Table 9.1). No surveys were done for the 24 colonies in the SCP and three colonies in the DNP after 1993. No surveys were done for one colony in the NNP after 1994 (Table 9.1). No surveys exist after 1995 for five colonies in South Africa (Table 9.1).

Angola has one confirmed breeding colony, 30 km north of the Cunene River (Simmons 2010, Tables 9.1 and 9.2). Most breeding colonies are found in

Namibia (57; 24 in SCP, 23 in DNP, three in NNP, seven in SNP) and 12 colonies are found in South Africa (Tables 9.1 and 9.2).

Twenty-four colonies had maximum estimates of less than 10 pairs, 20 colonies had maximum estimates of 11–20 pairs, 10 colonies had maximum estimates of 21–40 pairs, 10 colonies had maximum estimates of 41–70 pairs, and six colonies had maximum estimates that were above 100 pairs (Table 9.2). The smallest colonies had a maximum estimate of one pair and included Ugab Saltworks Pan, Horingbay, Guano Bay in Namibia and Cape Recife in South Africa (Table 9.2, Figures 9.3, 9.4 and 9.5). These colonies differ from single pairs because they were known to return to the same area each year. A minimum estimate of zero pairs at some colonies indicate that these are likely to be extinct. All of the colonies with more than 30 pairs were in Namibia, although one was tentatively identified in Angola (Table 9.2).

The largest colony was at Hottentots Bay (187–300 pairs), followed by Durissa Bay Pans, Caution Reef and Meob Bay, all of which occur in Namibia (Tables 9.1 and 9.2). If the maximum estimate of the Angolan colony 30 km north of Cunene River is reasonably accurate, then this colony is the second largest colony globally, after Hottentots Bay (Table 9.2). However the wide range of estimates for this colony implies a large margin of uncertainty (Table 9.2).

Between 100–400 single pairs are estimated to breed between colonies in the SCP and the DNP (Table 9.2). Altogether 20 pairs were estimated between Meob Bay and Hottentots Bay (Braby *et al.* 2001, Table 9.2); the rest of the NNP is not suitable habitat. No single pairs were found outside of colonies in the SNP. Therefore, the number of single pairs in the SNP was estimated to range between 0 and 10 pairs (Table 9.2).

The global population of Damara Terns is estimated to range between 1001–2685 pairs, or 2002–5370 breeding individuals (Tables 9.2 and 9.3). The minimum estimate of 2002 individuals represents the absolute minimum. Of these minimum and maximum estimates, 1–5% (6–190 pairs) occur in Angola, 87–93% (930–2347 pairs) occur in Namibia, and 6% (65–148 pairs) occur in South Africa (Table 9.2). Within Namibia, most pairs bred in the SCP (301–770 pairs). The DNP supported 237–571 pairs, the NNP had the smallest number of pairs (47–185) and the SNP had 225–391 breeding pairs (Table 9.2).

Discussion

Breeding population estimates

The minimum estimate of 2002 breeding individuals represents an absolute minimum, because many colonies were not surveyed thoroughly and population sizes at them represent underestimates of the true population. The population is therefore more likely to approach the maximum of 5370 breeding individuals. Apart from the estimate of 7000 breeding individuals by Braby *et al.* (1992) and 13500 breeding individuals by Simmons *et al.* (1998a), most previous estimates of the total population size of Damara Terns were lower than or similar to those reported in this study (Table 9.3).

In March 1991, a group of 5068 Damara Terns was seen 178 km south of the Cunene River, of which an estimated 4004 were adults (Braby *et al.* 1992). Additional flocks, and Damara Terns still breeding during this time in northern Namibia, were added to this count, along with an extrapolated estimate of 1940 birds from Angola to give a total 7000 adults and juveniles (of which 5600 were adults and 1400 were juveniles). My study included only breeding adults (i.e. birds three to four years old and older; Chapter 4); and my estimate therefore is similar to the 5600 adults estimated by Braby *et* *al.* (1992). It is also likely that the discrepancy between estimates obtained by Braby *et al.* (1992) and this study is either due to an overestimate of the Angolan breeding population by Braby *et al.* (1992) or an underestimate here. An underestimate in my study is possible, because there may be more than one colony in Angola (Simmons *et al.* 2006, Table 9.1). Alternatively, the discrepancy may reflect a decline of the breeding population since 1992.

The estimate of up to 5370 breeding Damara Terns is substantially lower than the 13500 individuals estimated by Simmons *et al.* (1998a). They sampled random blocks (measuring 1000 m each) inside and outside known colonies and extrapolated actual counts across the entire breeding habitat of the Namib Desert coastline. Damara Terns breed in colonies and display fidelity to the same sites (Chapter 5) and these sites only take up small percentages of the entire available breeding habitat (Randall and McLachlan 1982, Chapter 7). Small numbers of scattered single pairs breed outside of these colonies. Thus, extrapolating counts obtained from sampling within colonies across all suitable habitats, including those known not to support breeding Damara Terns, would overestimate the breeding population. If only those counts that were made in blocks containing scattered breeding pairs had been used to extrapolate across the entire suitable breeding habitat, added to the numbers found at each colony, the population estimate might have been similar to that obtained here.

Kemper *et al.* (2007) estimated the breeding population to number around 930 pairs. This is an underestimate, because estimates for the Angolan breeding population were not then available and there were no estimates for the area between the Cunene River and Möwe Bay. In addition, the population at Hottentots Bay was underestimated, because the extent of this colony was only ascertained after 2008. If this additional information had been included, the total estimate by Kemper *et al.* (2007) would have been compatible with that obtained here.

The estimate of breeding pairs in Angola is based on only one confirmed colony (Simmons 2010) and is therefore likely to be biased low. Apart from the estimate of 1940 breeding individuals by Braby *et al.* (1992), no other estimates exist for that region. This estimate was based on extrapolating birds counted per kilometer in northern Namibia to similar habitat in southern Angola and may have therefore represented an upper limit. However, counts of 280 Damara Terns in breeding plumage along 203 km of coastline during December–January north of the confirmed colony implies that there could be additional colonies in Angola (Table 9.1).

Only Clinning (1978) separately estimated the Namibian breeding population of Damara Terns; his estimate was similar to that obtained here. His relatively low estimate may have been indicative of a lack of accessibility to and information on breeding sites (Table 9.3).

Previous estimates of the South African breeding population were roughly 120 pairs (Barnes 2000, Table 9.3). This is similar to the estimates of this study.

Crawford and Simmons (1997) suggested that 98% of the global breeding population occurs in Namibia. This revision concludes that up to 93% of Damara Terns breed in Namibia with substantial populations breeding in Angola and South Africa (at least 1–5% for Angola, 6% for South Africa).

Trends in the breeding population

Breeding estimates have fluctuated greatly in the past (Table 9.3) and it is difficult to discern any concrete trends, because of the different census methods that were used. However, it is likely that the overall population has declined in the past century.

No information on possible decreases is available for Angola. In Namibia, coastal development resulted in the extinction of some colonies (Table 9.1, R.J. Braby unpubl. data). Andersson (1872) found Damara Terns breeding where Walvis Bay is presently situated, and described them as being common, as did Frost and Shaughnessy (1976) less than four decades ago. There must have been breeding colonies in areas where the towns Swakopmund and Hentiesbay are now situated. Development at Wlotzkasbaken has also resulted in the decrease or even possible extinction of the breeding colony there (Tables 9.1 and 9.2). Dolphin Beach, a colony that supported at least 32 pairs in 2005/06 is now covered with houses and apartment complexes (Table 9.1, R.J. Braby unpubl. data), and it is unlikely that birds still breed within this vicinity.

In South Africa, previous estimates of the breeding populations have decreased from 150 pairs to 120 pairs in the 1990s (Barnes 2000, Table 9.3). Estimates in this study for South Africa indicate that the population there has, at best, increased slightly, and at worst, decreased substantially. It is likely that the number of breeding pairs lies closer to the minimum estimate obtained here, suggesting that breeding birds have decreased considerably in South Africa in the past decade.

Threats to breeding colonies and populations

There are a number of threats faced by Damara Terns throughout their breeding range. These are listed below:

1. Coastal development causing colony extinctions (Vincent 1946, R.J. Braby unpubl. data). Coastal development has been the major

cause of declines in similar species, such as the Least Tern *Sterna antillarum* populations in North America and Europe (Norman and Saunders 1969, Cramp *et al.* 1974, Wilbur 1974, Massey 1974, Gore and Kinnison 1991, Koenen *et al.* 1996, Zuria and Mellink 2002, Akçakaya *et al.* 2003, Elliot *et al.* 2007). The habitat of the Little Tern *Sterna albifrons* has diminished and thus resulted in the construction of artificial breeding habitats such as salinas in Portugal (Catry *et al.* 2004) and land reclamations for breeding areas in Japan (Fujita *et al.* 2009). The largest colony of the Peruvian Tern *Sterna lorata* is losing breeding habitat to industrial development at Pampa de Mejillones in northern Chile (C. Guerra pers. comm., pers. obs.).

2. Off-road driving causing disturbance to breeding areas resulting in low reproductive success (Braby *et al.* 2001, Williams *et al.* 2004, S.J. Braby unpubl. data). Damara Terns in the DNP are directly impacted by off-road driving (Braby *et al.* 2001, Chapter 8, S.J. Braby unpubl. data, MET unpubl. data, pers. obs, N. Dreyer pers. comm.). The DNP is popular with tourists, especially off-road enthusiasts and fishermen, and the summer holiday season coincides with the Damara Tern breeding season. In South Africa, off-road driving had negative impacts in the past (Watson 1995, 1997, 1999) but beach-driving is banned as from 2001 (Williams *et al.* 2004). This resulted in increased breeding success at one colony (Williams *et al.* 2004).

3. Anthropogenic activities that result in increases in predator densities (e.g. offal from fishing attracting more Black-backed Jackals *Canis mesomelas*, R.J. Braby pers. comm.).

4. Diamond mining causing direct and/or indirect disturbance to breeding areas (Connor 1980, Brooke 1984, Simmons 2005b, Chapter 7).

Diamond mining has not recently had direct negative impacts on breeding terns in the SNP (Chapter 7). However, new diamond mining technology is focusing on inshore and surf zone mining activities in the SNP and this may have a negative impact on the feeding grounds of breeding Damara Terns. Prospecting in the SCP may cause disturbances to breeding colonies (e.g. at Sarusas, Figure 9.2). If prospecting leads to full-scale mineral extraction in the vicinity of breeding colonies in the SCP, full-scale mineral extraction is likely to have a negative impact on breeding Damara Terns.

5. Effects of climate change, including increased tidal flooding of large, low-lying colonies such as at Hottentots Bay (pers. obs), increasing fluctuations of food availability as a result of decreased upwelling and increased sea surface temperature (Roux 2003, Chapter 2).

6. The capture of Damara Terns for sale and/or food in Angola (Annex 1). No information exists regarding the scale of this trade.

Current and recommended conservation measures

There are various conservation measures that have been put in place in all three countries that assist in protecting breeding terns. These, and recommendations for further protection, are discussed below.

<u>Angola</u>:

The breeding area of the Damara Tern in Angola is largely uninhabited, inaccessible to humans and is legally protected as it falls within the Iona National Park (IUCN 1992). However, local people trap and kill seabirds, including (mostly migrating) Damara Terns, along the coastline, and even within the Iona National Park (Annex 1, T. de Wit pers. comm.). This practice is also conducted in other migratory countries (Braby 2010). How many

Damara Terns are killed this way, however, is unknown. Although Angola is signatory to the Convention on Migratory Species, no national law or enforcement exists that protects the Damara Tern there. It is imperative that the number of Damara Terns killed in this way be investigated in Angola and all migration countries to ascertain the level of threat of this practice to the species. Laws protecting the biodiversity and efficient enforcement of these laws would greatly reduce this practice.

Namibia:

The Damara Tern is "Specially Protected" under the draft Protected Areas and Wildlife Management Bill. Most colonies are protected because they fall within the boundaries of protected areas (Chapter 1). However, mining and prospecting is still allowed within these areas. It is mandatory for any proposed activity (like mining) to conduct an Environmental Impact Assessment under the Environmental Management Act (Act 7 of 2007) and its draft Environmental Impact Assessment (EIA) regulations and accompanying Strategic Environmental Assessment (SEA) for each coastal area.

Namibia's first marine protected area, the Namibian Islands' Marine Protected Area, (NIMPA), promotes the protection of feeding grounds from Meob Bay to Chameis Bay (e.g. through restrictions on mining activities, including the building of seawalls).

The entire coastline of Namibia is protected by the provisionally-named Namib-Skeleton Coast National Park, which includes the Skeleton Coast Park, Dorob National Park, Namib-Naukluft Park and Sperrgebiet National Park (and effectively a transfrontier park as it will incorporate the Iona National Park in Angola and the Richtersveld National Park in South Africa). Within this mega-park, the significant breeding areas of Damara Terns will receive special protection because they will fall under Important Bird Areas (IBA) that are conservation priority zones. These will be protected by SEA and park management plans.

Off-road driving continues to be a problem on the Namibian coastline, and is at its largest level in the DNP during holiday season. There has been some conservation success by prohibiting access to two colonies between Swakopmund and Namibia, Horses Graves and Caution Reef (Braby *et al.* 2001, Chapter 8). However, many off-road drivers are unaware of the level of disturbance and destruction they cause (Plate 2). ORV disturbance is considered a significant threat to breeding Damara Terns, therefore it is important to continue awareness campaigns and prohibit access to important breeding areas during breeding season. A permit system is in place to protect breeding areas and prevent irreparable damage to the desert coastline of Namibia, but this is weakly enforced. The area between Swakopmund and the Ugab River (in the DNP) is heavily utilized by ORVs and there are virtually no enforced restrictions on drivers (Plate 2). Strengthened enforcement of ORV regulations by Namibia's Ministry of Environment and Tourism in the DNP could decrease ORV destruction and better protect breeding areas. Off-road regulations in isolated areas of the SCP and SNP should also be enforced through induction courses for prospectors and mining personnel driving in areas where Damara Terns may breed.

Recreational beach-users should be actively encouraged through Communication, Education and Public Awareness (via the Ministry of Environment) to not leave their offal on the beach when they depart. This may be one way to decrease the densities of jackals patrolling the beach.

<u>South Africa:</u>

Off-road driving has been banned on South Africa's beaches and breeding Damara Terns have responded positively to this (Williams *et al.* 2004). The National Environmental Management Act (Act 107 of 1998) and its associated regulations, which have been updated in 2010 (published under Government Notice R543–546 on 18 June 2010), and the National Environmental Biodiversity Act (Act 10 of 2004) , ensure the legal protection of the Damara Tern in South Africa. However, many colonies occur in restricted diamond mining areas in the Northern Cape and the protection of the species in these areas is weakly enforced, if at all. The mining companies in these areas should be encouraged to cordon off breeding areas and protect them from disturbance, and areas that have been disturbed (e.g. Alexander Bay, Table 9.1, Figure 9.4), should be rehabilitated.

Data: limitations, weaknesses and recommendations

There are various gaps and shortcomings in the available data on population size estimates. These need to be discussed along with recommendations to ensure reliable estimates and thus allow the accurate calculation of population trends in future:

Angola:

The estimates of breeding pairs in Angola in this study may be slightly low, because they are based on only one confirmed colony (Simmons 2010). Two potential colonies were found in 2009 (Simmons 2010) and it is possible that other small colonies exist there. Concerted efforts need to be made to survey this area properly and to verify the northern limit of the species' breeding range, thought to be as far north as Namibe (15°10'S 12°10'E, R. Sakko pers comm.).

Nambia:

There is a need for a comprehensive survey of the entire Namibian coastline to ascertain proper estimates of breeding populations within and outside of colonies. This was first suggested at the Namibian Coastal-Marine Bird Action Plan workshop in April 2008 (NACOMA 2008). The areas in urgent need of surveys are outlined below:

1. SCP

The colonies in the SCP have not been monitored or surveyed since the mid-1990s. Incidental observations since then have confirmed that most colonies are still present (Paterson pers. comm., Table 9.1). However, there has been a large-scale shift in Cape Fur Seal *Arctocephalus pusillus pusillus* distribution northwards into the SCP (Kirkman *et al.* 2007). This is likely to increase food availability for scavenging Black-backed Jackals that in turn may result in an increase in jackal densities in this area. Jackals are the most common predators of Damara Tern eggs and chicks and an increase in predator population is likely to negatively impact breeding success and numbers of terns in the SCP. A thorough survey needs to be conducted of all the colonies in the SCP to attain current estimates and to ascertain any decreases in breeding populations.

2. DNP

While Horses Graves and Caution Reef colonies have been monitored intensively for over a decade, there are some colonies for which information on breeding pair numbers is outdated (Table 9.1). Although short-term surveys have indicated that these colonies still exist (Table 9.1), more intensive surveys should be completed during the height of the breeding season to obtain more up-to-date information, especially at Durissa Bay Pans, White Stones and Mile 72.

3. NNP

Data for Conception and Meob Bay are lacking apart from a few short-term surveys and anecdotal reportings. This area, especially Meob Bay, is likely to hold a substantial population of breeding Damara Terns and needs to be monitored to ascertain threats, success and breeding numbers. Jackal densities are relatively high in these areas (R.J. Braby pers. comm.), thus the breeding success needs to be measured to investigate the importance of this colony and to assess the need and viability of implementing worthwhile conservation measures here.

4. SNP

Intensive and long-term monitoring has been conducted for the SNP north to Hottentots Bay over two and a half breeding seasons. For various reasons, only about a third of the possible breeding area of Hottentots Bay could be monitored and therefore the remaining two thirds of the breeding area should be surveyed.

<u>South Africa:</u>

Although the proportion of Damara Terns breeding in South Africa is low, its status as a locally endangered species (Barnes 2000) highlights the necessity for a comprehensive inventory of breeding colonies and good quality population size estimates. Colony sizes range from one to a maximum of 30 pairs (Table 9.2), but most have been poorly searched. The breeding population at Brandfontein and de Hoop are likely to be small, however a survey during the height of the breeding season should be conducted here to ensure accuracy. The information for Alexander Bay and the surrounding breeding areas is outdated (last surveyed for nests in 1996). In addition, surveys were not conducted over a long enough time period to acquire more accurate counts. These areas need to be surveyed thoroughly to obtain more current and accurate estimates.

Recommendation regarding conservation status

The Near-threatened IUCN status for the Damara Tern was based on the population estimate of 13500 mature individuals by Simmons *et al.* (1998, IUCN 2009). The estimate of this study of up to 5370 mature individuals suggests a decline of more than 60% in the past 12 years. This suggested decline, along with the small number of mature individuals, and uncertainties of future declines, fulfill the IUCN criteria for the Damara Tern to be uplisted to Vulnerable (IUCN 2000). However, this study suggests an overestimate by Simmons *et al.* (1998a) and that the population has, in fact, not declined to this reflected extent. In addition, most of the species breeding ground is (or will be) found in protected areas, thus lowering the risk of catastrophic extinction in the future. I suggest that the species remain listed as Near-Threatened. However, a re-evaluation of the species conservation status should be performed after an urgent survey of the entire breeding population is completed.

Table 9.1: Nest counts and surveys, including counts of adults and fledglings, at all known breeding colonies of Damara Terns in Angola, Namibia and South Africa. Method number refers to survey effort (1=long-term monitoring, 2=short-term monitoring, 3=short surveys/anecdotal nest records) as detailed in the Study area and Methods. Fledglings are young birds that have recently fledged and are thus assumed to have been hatched at the colony they were found, juveniles are young birds that have fledged that season and *may* have been hatched at another colony if counted at a colony during migration months (e.g. from January onwards). MET stands for Ministry of Environment and Tourism of Namibia.

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
ANGOLA						
Tombua to Baia dos Tigres and surrounds	*c.* S15°47 E12°09 to S16°26 E11°43	3	20 Dec 1998–4 Jan 1999	Simmons *et al.* 2006	–0	280 adults, 203 km of coastline
30km North of Cunene	S16°58 E11°46	3	24–26 January 2009	Simmons 2010	6	573 (7.5% juveniles) Damara Terns
NAMIBIA						
Skeleton Coast Park/ Northern Namibia						
Cunene Surrounds	S17°16 E11°44	3	5 Feb 1992	MET unpubl. data	2	
40km South of Cunene	S17°30 E11°44	3	6–7 Feb 1992	MET unpubl. data	3	9 adults
100km South of Cunene	S18°09 E11°54	3	7 Feb 1992	MET unpubl. data	3	100 adults
Between Angra Fria and Cape Frio	S18°17 E11°58	3	8 Feb 1992	MET unpubl. data	3	144 adults, 9 juveniles

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
		3	8 Feb 1992	MET unpubl. data	–	15 - 20 adults
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
Sarusas	S18°44 E12°21	3	8 Feb 1992	MET unpubl. data	2	
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
Westies Mine	S19°11 E12°37	3	8–9 Feb 1992	MET unpubl. data	2	
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
5km North-East of Möwe Bay	S19°19 E12°43	3	Feb–Mar 1991	MET unpubl. data	3	
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
Möwe Bay Airstrip	S19°22 E12°43	3	December 1990 - March 1991	MET unpubl. data	8	
		2	Feb 1993	MET unpubl. data	62	
		3	January 2006	Patterson unpubl. data	6	no thorough search for nests were made
13km South of Möwe Bay	S19°27 E12°44	3	Mar –Apr 1995	MET unpubl. data	4	
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
30km South of Möwe Bay	S19°32 E12°47	3	10 Feb 1992	MET unpubl. data	5	
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
50km South of Möwe Bay	S19°44 E12°55	3	26 Jan–19 Mar 1991	MET unpubl. data	8	

Breeding colonies	**Geographical Position**	**Method number**	**Date(s)**	**Source**	**No of nests**	**Extra Information**
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
60km South of Möwe Bay	S19°49 E12°57	3	14 Mar 1981	MET unpubl. data	1	
		2	21 Dec 1990–11 Apr 1991	MET unpubl. data	27	
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
Saltpans North of Terrace Bay Landing Strip	S19°55 E13°00	3	14 Mar 1981	MET unpubl. data	1	
		3	5–12 Jan 1987	MET unpubl. data	8	16 adults, gulls and crows present and high risk
		3	10–11 Feb 1992	MET unpubl. data	6	
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
Terrace Bay surrounds	S19°58 E13°03	3	10 Feb 1992	MET unpubl. data	2	
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
Swallow Breakers surrounds	S20°03 E13°03	3	17 Feb 1981	MET unpubl. data	9	
		3	7 Jan 1987	MET unpubl. data	7	
		3	11 Feb 1992	MET unpubl. data	18	not much more
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
6km North of Torrabay	S20°14 E13°13	3	18 Jan 1987	MET unpubl. data	4	
		3	11–12 Feb 1992	MET unpubl. data	2	

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
Torrabay	S20°18 E13°14	3	6 Jan 1984	MET unpubl. data	1	
		3	30 Mar–7 Apr 1985	MET unpubl. data	2	
		3	4–5 Dec 1991	MET unpubl. data	11	+ 3 suspected nests
		n/a	2009	J. Patterson pers. comm.	–	Colony still exists
Henriette Pashette Saltpan	S20°21 E13°15	3	3–6 Feb 1990	MET unpubl. data	1	
		3	9–12 Dec 1991	MET unpubl. data	4	
		3	12 Feb 1992	MET unpubl. data	3	small colony on fringes of pan
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
Black Gravel Plains North of Koigab	S20°26 E13°16	3	16–20 Jan 1984	MET unpubl. data	1	+ 1 pair mobbing
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
		3	12 Feb 1992	MET unpubl. data	1	
Montrose Saltpan	S20°32 E13°18	3	Feb 1981	MET unpubl. data	–	31 adults, 4 fledglings
		3	31 Mar 1986	MET unpubl. data	11	
		3	8 Dec 1991	MET unpubl. data	2	
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
Red Plains	S20°38 E13°21	3	26 Dec 1983, 1 Jan, 14 Jan 1984	MET unpubl. data	2	30 adults, very noisy

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
		3	9 Dec 1984–18 Feb 1985	MET unpubl. data	6	
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
Toscanini Saltpans	S20°47 E13°23	3	28 Jan 1984	MET unpubl. data	1	
		3	20 Jan 1985	MET unpubl. data	1	
		3	10 Mar–1 Apr 1986	MET unpubl. data	4	6 adults, 2 juveniles
		2	Nov 1991–Feb 1992	MET unpubl. data	22	
		3	23 Nov–13 Dec 1992	MET unpubl. data	1	
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
Huab	S20°50 E13°26	3	3–27 Jan 1985	MET unpubl. data	4	
		3	15 Jan–12 Feb 1987	MET unpubl. data	5	
		2	Nov 1992–Jan 1993	MET unpubl. data	39	85 adults, 3 fledglings
		n/a	2009	J. Patterson pers. comm.	–	colony still exists
Ugab River to Ogden Rocks	S21°05 E13°33	3	Dec 1983 – Apr 1984	MET unpubl. data	14	
		3	Dec 1984–Jan 1985	MET unpubl. data	7	
		3	Feb–Mar 1986	MET unpubl. data	3	
		3	Jan – Feb 1987	MET unpubl. data	10	
		3	24 Nov–7 Dec 1991	MET unpubl. data	2	
		2	Nov 1992–Jan 1993	MET unpubl. data	24	
		n/a	2009	J. Patterson pers. comm.	–	colony still exists

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
Dorob National Park						
SCP fence	S21°11 E13°36	3	14 Jan 1985	MET unpubl. data	1	8 adults
6km South of Ugab	S21°13 E13°40	3	20 Jan 1985	MET unpubl. data	1	6 adults
Durissa Bay Pans	S21°15 E13°41	3	28 Dec 1983–3 Mar 1984	MET unpubl. data	11	
		3	26 Dec 1984–28 Mar 1985	MET unpubl. data	18	
		3	28 Feb–4 Mar 1991	MET unpubl. data	1	
		3	21 Nov 1991–31January 1992	MET unpubl. data	17	
		2	1 Nov 1992–8 Jan 1993	MET unpubl. data	123	
		3	29–30 Dec 1997	MET unpubl. data	3	
		3	Dec 2009–Feb 2010	J. Braby unpubl. data	24	
Ugab Saltworks Pan	S21°22 E13°46	3	8–15 Jan 1984	MET unpubl. data	1	
		3	21 Jan 2010	J. Braby unpubl. data	0	
Mile 108	S21°28 E13°50	3	Dec 1983–Jan 1984	MET unpubl. data	5	
		3	Nov 1984 – Jan 1985	MET unpubl. data	7	
		3	19 Dec 2009	J. Braby unpubl. data	–	6 adults
Mile 100	S21°31 E13°51	3	10–19 Jan 1984	MET unpubl. data	1	
		3	8–9 Jan 1985	MET unpubl. data	3	
		3	5 Jan 1995	MET unpubl. data	2	
		3	13 Feb 2010	J. Braby unpubl. data	1	2 adults, 1 fledgling

Breeding colonies	**Geographical Position**	**Method number**	**Date(s)**	**Source**	**No of nests**	**Extra Information**
Horingbay	S21°34 E13°53	3	10–11 Jan 1984	MET unpubl. data	1	
		3	Jan–March 2010	J. Braby unpubl. data	0	
White Stones	S21°39 E13°58	3	9 Jan 1985	MET unpubl. data	1	
		3	Jan–Mar 2010	J. Braby unpubl. data	11	22 adults, 5 fledglings
Cape Cross surrounds	S21°45 E13°58	3	31 Dec 1977	Underhill and Whitelaw 1977	–	2 adults
			1990s	MET unpubl. data	3	no extensive searches made
Mile 72 Camp and Saltpan	S21°53 E14°05	3	28 Nov – 9 Dec 1992	MET unpubl. data	3	
		2	20 Dec 1994–19 Jan 1995	MET unpubl. data	36	
		3	13 Feb 2010	J. Braby unpubl. data	10	20 adults
Mile 72 Saltworks Pan	S21°54 E14°06	3	11 Jan 1977	Underhill and Whitelaw 1977	–	48 adults
		2	Dec 1992–Jan 1993	MET unpubl. data	30	
		2	Dec 1994–Jan 1995	MET unpubl. data	16	
		3	13 Feb 2010	J. Braby unpubl. data	0	1 adult, 3 fledglings
North of Hentiesbay	S22°01 E14°14	3	11 Jan 1984	MET unpubl. data	3	nests widely dispersed
		3	3 Dec 1981	MET unpubl. data	2	
		3	21 Jan 2010	J. Braby unpubl. data	0	6 adults
Jakkalsputz	S22°12 E14°21	3	11 Jan 1984	MET unpubl. data	1	
		3	3–5 Mar 1986	MET unpubl. data	2	
		2	Nov 1991–Jan 1992	MET unpubl. data	14	

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
		2	28 Nov–8 Dec 1992	MET unpubl. data	4	
Shipwreck	S22°14 E14°21	3	10 Jan 2010	J. Braby unpubl. data	0	11 adults, 2 fledglings
		3	21 Jan 2010	J. Braby unpubl. data	0	11 adults, 2 fledglings
		3	6 Feb 2010	J. Braby unpubl. data	0	11 adults, 2 fledglings
		3	12 Mar 2010	J. Braby unpubl. data	0	208 adults, 34 juveniles
Pebbles	S22°16 E14°23	2	Jan 1984–Feb 1984	MET unpubl. data	2	
		3	21 Jan 2010	J. Braby unpubl. data	0	3 adults
Mile 30	S22°18 E14°24	2	14 Nov 1991–5 Jan 1992	MET unpubl. data	9	2 juveniles
		3	Jan–Mar 2010	J. Braby unpubl. data	0	
Wlotzkasbaken	S22°21 E14°25	3	4, 9 Jan 1977	Underhill and Whitelaw 1977	–	21 adults
		2	Nov 1991–Jan 1992	MET unpubl. data	17	
		2	Nov 1992–Jan 1993	MET unpubl. data	10	
		3	Jan–Mar 2010	J. Braby unpubl. data	0	Possibly extinct due to housing development
Mile 8	S22°31 E14°29	3	4 Jan 1977	Underhill and Whitelaw 1977	–	8 adults
		3	Jan–Feb 2010	J. Braby and M. Boorman unpubl. data	2	20 adults, 1 juvenile
Mile 4	S22°35 E14°31	3	1 Jan 1977	Underhill and Whitelaw 1977	–	24 adults
		2	Austral Summers 2007/08, 2008/09, 2009/10	M. Boorman pers. comm.	n/a	10–20 pairs

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
Horses Graves	S22°42 E14°33	1	Sept 2001–March 2002	Braby *et al.* 2009 (Chapter 8)	59	
		1	Sept 2002–March 2003	Braby *et al.* 2009 (Chapter 8)	122	
		1	Sept 2003–Mar 2004	R.J. Braby unpubl. data (Chapter 2)	89	
		1	Sept 2004–Mar 2005	R.J. Braby unpubl. data (Chapter 2)	97	
		2	Sept 2005–Mar 2006	S.J. Braby unpubl. data (Chapter 2)	32	
		1	Sept 2006–Mar 2007	S.J. Braby unpubl. data (Chapter 2)	69	
		1	Sept 2007–Mar 2008	S.J. Braby unpubl. data (Chapter 2)	56	
		2	Sept 2008–Mar 2009	S.J. Braby unpubl. data (Chapter 2)	54	
		1	Sept 2009–Mar 2010	S.J. Braby unpubl. data (Chapter 2)	45	
Caution Reef	S22°44 E14°32	3	1 Jan 1977	Underhill and Whitelaw 1977	–	6 adults, beach count
		1	Sept 1994–Mar 1995	Braby 1995	120	
		2	Dec 1997–Jan 1998	Reiss and Kruger 1998	48	
		1	Sept 2000–Mar 2001	R.J. Braby unpubl. data (Chapter 2)	48	
		1	Sept 2001–March 2002	R.J. Braby unpubl. data	92	

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
				(Chapter 2)		
		1	Sept 2002–March 2003	R.J. Braby unpubl. data (Chapter 2)	56	
		1	Sept 2003–Mar 2004	R.J. Braby unpubl. data (Chapter 2)	40	
		1	Sept 2004–Mar 2005	R.J. Braby unpubl. data (Chapter 2)	60	
		2	Sept 2005–Mar 2006	S.J. Braby unpubl. data (Chapter 2)	13	
		1	Sept 2006–Mar 2007	S.J. Braby unpubl. data (Chapter 2)	92	
		1	Sept 2007–Mar 2008	S.J. Braby unpubl. data (Chapter 2)	52	
		1	Sept 2008–Mar 2009	S.J. Braby unpubl. data (Chapter 2)	71	
		1	Sept 2009–Mar 2010	S.J. Braby unpubl. data (Chapter 2)	108	
Dolphin Beach	S22°50 E14°32	3	2 Jan 1977	Underhill and Whitelaw 1977	–	12 adults, beach count
		3	6–7 Jan 2004	R.J. Braby unpubl. data	4	
		2	Nov 2004–Jan 2005	R.J. Braby unpubl. data	32	most failed due to development, breeding area now consists of housing development

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
Pelican Point	S22°56 E14°25	3	6 Jan 1977	Underhill and Whitelaw 1977	–	1 adult
		2	Regular visits during summer 2007–2009	N. Dreyer pers. comm.	n/a	8–15 pairs
Namib-Naukluft Park						
Sandwich Harbour	S23°09 E14°28	3	7 Jan 1977	Underhill and Whitelaw 1977	–	60 adults
		3	14–16 Dec 1993, 6–7 Jan 1994	MET unpubl. data	18	6 adults, 2 juveniles
		3	20 Dec 1997	MET unpubl. data	6	
		2	Regular visits during summer 2007–2009	N. Dreyer pers. comm.	n/a	15–35 pairs
Conception Bay	S23°51 E14°28	3	5–10 Dec 1994	MET unpubl. data	14	12 adults
Meob Bay	S24°22 E24°42	3	11–18 Dec 1994	MET unpubl. data	18	3 adults + 70 adults between Moeb and Conception
		3	27 Feb 1997	MET unpubl. data	3	
		3	02 Jun 2008	R.J. Braby unpubl. data	1	30 adults, more nests suspected
		3	08 Oct 2008	R.J. Braby unpubl. data	0	>20 pre-breeding adults
Sperrgebiet National Park/Southern Namibia						
Hottentots Bay	S26°19 E14°58	3	? Dec 1977	Siegfried and Johnson 1978	9	
		3	18 Dec 1991	de Villers and Simmons 1997	11	more nests suspected

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
		3	11 Jan 1995	MRMR unpubl. data	est. 50	3 adults
		3	5–8 Jan 1996	MET unpubl. data	12	
		3	Jan–Mar 2007	J. Braby unpubl. data (Chapters 2,7)	17	
		2	Oct 2007–Mar 2008	J. Braby unpubl. data (Chapters 2,7)	80	
		2	Oct 2008–Mar 2009	J. Braby unpubl. data (Chapters 2,7)	187	596 adults (maximum count in surveyed area of pan)
Guano Bay	S26°39 E15°06	2	Jan–Mar 2007	J. Braby unpubl. data	1	
		1	Oct 2007–Mar 2008	J. Braby unpubl. data	0	
		1	Oct 2008–Mar 2009	J. Braby unpubl. data	0	
Grosse Bucht	S26°43 E15°40	3	31 Dec 1995–18 Jan 1996	MET unpubl. data	11	
		2	Jan – Mar 2007	J. Braby unpubl. data (Chapters 2,7)	7	
		1	Oct 2007–Mar 2008	J. Braby unpubl. data (Chapters 2,7)	21	
		1	Oct 2008–Mar 2009	J. Braby unpubl. data (Chapters 2,7)	17	
Elizabeth Bay	S26°54 E15°14	3	10–18 Dec 1976	Frost and Johnson 1977	5	30 adults, 2 juveniles, 12 - 15 pairs
		3	1–7 Dec 1977	Siegfried and Johnson 1978	10	possibly 5 more nests, ca. 20 pairs

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
		3	8–10 Dec 1978	Johnson 1979	13	possibly 4 more, *c.* 20 pairs
		3	11–15 Jan 1996	Simmons 2005b	2	
		3	2 Feb 1997	MFMR unpubl. data	–	31 adults
		3	22 Nov 2002	Simmons 2005b, R.E. Simmons unpubl. data	3	4 juveniles, one courting pair, 8 adults, >8 pairs
		2	Jan–Mar 2007	J. Braby unpubl. data (Chapters 2,7)	3	40 adults, juveniles incl.
		1	Oct 2007–Mar 2008	J. Braby unpubl. data (Chapters 2,7)	13	
		1	Oct 2008–Mar 2009	J. Braby unpubl. data (Chapters 2,7)	4	
Possession Island	S27°05 E15°11	2	Sept 2004–Dec 2004	MFMR unpubl. data	0	12 adults, some may be from Elizabeth Bay
		2	Oct 2005–Jan 2006	MFMR unpubl. data	0	10 adults, some may be from Elizabeth Bay
		2	Oct 2006–Apr 2007	MFMR unpubl. data	2	12 adults, some may be from Elizabeth Bay
		2	Sept 2007–Mar 2008	MFMR unpubl. data	2	6 adults, some may be from Elizabeth Bay
Marmora Pan	S27°44 E15°34	3	Jan 1996	R.E. Simmons pers. comm.	10	
		3	5 Feb 2007	J. Braby unpubl. data (Chapters 2,7)	2	38 adults, at least 2 juveniles

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
		1	Oct 2007–Mar 2008	J. Braby unpubl. data (Chapters 2,7)	55	
		1	Oct 2008–Mar 2009	J. Braby unpubl. data (Chapters 2,7)	13	
Chameis Pan	S27°54 E15°41	3		R.E. Simmons and I. Cordes unpubl. data	10	
		3	10 Jan 2008	J. Braby unpubl. data	1	3 adults
SOUTH AFRICA						
Alexander Bay	S28°29 E16°29	3	31 Dec 1995	J. Cooper and L.G. Underhill, unpubl. data	–	29 adults, 4 juveniles
		3	Jan–Feb 2007	J. Braby unpubl. data	–	30 adults
Port Nolloth Pan	S29°14 E16°52	3	18 Dec 1995	J. Cooper and L.G. Underhill, unpubl. data	5	15 adults
		2	Jan 2006	J. Cooper and L.G. Underhill, unpubl. data	6	16 adults
		1	Austral summer 2006/07	J. Lonser unpubl. data	10	20 adults
		1	Austral summer 2007/08	J. Lonser unpubl. data	10	20 adults
Oubeep Pan	S29°19 E16°57	3	18 Dec 1995	J. Cooper and L.G. Underhill, unpubl. data	3	5 adults
Dreyerspan	S29°31 E17°04	3	18 Dec 1995	J. Cooper and L.G. Underhill, unpubl. data	2	4 adults
		3	Sporadic 1990s	A. van Wyk pers. comm.	n/a	*c.* 20 pairs

Breeding colonies	**Geographical Position**	**Method number**	**Date(s)**	**Source**	**No of nests**	**Extra Information**
Karaspan	S29°34 E17°01	3	18 Dec 1995	J. Cooper and L.G. Underhill, unpubl. data	2	15 adults
Brandfontein	S34°46 E19°53	3	1990s, date unknown	P. Steyn pers. comm.	2	
Struisbay	S34°43 E20°00	1	Austral summers 1996–2002	Williams *et al.* 2004, Williams in prep.	11–13	11–13 pairs
De Hoop	S34°29 E20°27			R.E. Simmons pers. comm.	n/a	*c.* 2 pairs
Gouritz	S34°18 E21°52	3	9 Jan 1976	R.W. Summers, L.G. Underhill and P.G.H. Frost, unpubl. data	–	6 adults, 1 juvenile
		3	Dec 2009–Mar 2010	P. la Grange pers. comm.	0	
Cape Recife	S34°08 E25°48	3	5 Jan 2000	Tree 2000	–	2 adults, 1 juvenile
		2	Dec 2001–Jan 2002	Martin and Taylor 2000	1	3 fledglings
		3	28 Sept 2006	Crawford *et al.* 2009	–	13 adults courtship feeding
Coega	S33°46 E25°42	3	13 Dec 1990	Crawford *et al.* 2009	1	2 separate adults
		3	1 Dec 1999	Crawford *et al.* 2009	–	2 adults
		3	30 Nov 2007	Crawford *et al.* 2009	3	4 separate adults
		3	Austral summers 2007/08, 2008/09	P. Whittington pers. comm..	n/a	3–5 pairs
Alexandria Dune Fields	S33°42 E25°55	3	17 Jan 1979	Underhill *et al.* 1980	–	6 adults, Sundays River estuary
		1	Nov 1980–Mar 1981	Randall and McLachlan 1982	12	+5 adults
		1	Austral summer 1991/92	Watson *et al.* 1997	28	

Breeding colonies	Geographical Position	Method number	Date(s)	Source	No of nests	Extra Information
		1	Austral summers from 1991–1994	Watson 1995	n/a	15–20 pairs
		3	Dec 2005	Whittington and Klages 2006	1	12 adults, 1 juvenile
		3	Austral summer 2008/09	P. Whittington and T. Tree, unpubl. data	5	
		1	Austral summer 2009/10	P. Whittington and T. Tree, unpubl. data	20	40 adults roosting on beach at night on 10 Feb 2010

Table 9.2: Minimum and maximum estimates of breeding pairs of Damara Terns at all known breeding colonies in Angola, Namibia and South Africa

Breeding colonies	Minimum estimate	Maximum estimate
ANGOLA		
30km North of Cunene	6	190
Sub-total (Angola)	**6**	**190**
NAMIBIA		
Skeleton Coast Park (SCP)		
Cunene Surrounds	2	20
40km South of Cunene	5	20
100km South of Cunene	3	50
Between Angra Fria and Cape Frio	15	70
Sarusas	2	20
Westies Mine	2	20
5km North-East of Möwe Bay	3	6
Möwe Bay Airstrip	62	120
13km South of Möwe Bay	4	30
30km South of Möwe Bay	5	30
50km South of Möwe Bay	8	30
60km South of Möwe Bay	27	60
Saltpans North of Terrace Bay Landing Strip	8	16
Terrace Bay surrounds	2	2
Swallow Breakers surrounds	18	20
6km North of Torrabay	4	10
Torrabay	14	30
Henriette Pashette Saltpan	4	10
Black Gravel Plains North of Koigab	2	10
Montrose Saltpan	11	16
Red Plains	15	30
Toscanini Saltpan	22	50
Huab	39	50
Ugab River to Ogden Rocks	24	50

Breeding colonies	Minimum estimate	Maximum estimate
Sub-total (SCP)	**301**	**770**
Dorob National Park (DNP)		
SCP fence	1	8
6km South of Ugab	1	6
Durissa Bay Pans	80	123
Ugab Saltworks Pan	0	1
Mile 108	3	7
Mile 100	2	3
Horingbay	0	1
White Stones	16	50
Cape Cross Surrounds	3	10
Mile 72 Camp and Saltpan	10	36
Mile 72 Saltworks Pan	3	16
North of Hentiesbay	3	12
Jakkalsputz	1	14
Shipwreck	2	11
Pebbles	1	3
Mile 30	0	11
Wlotzkasbaken	0	17
Mile 8	3	15
Mile 4	10	20
Horses Graves	30	60
Caution Reef	60	100
Dolphin Beach	0	32
Pelican Point	8	15
Sub-total (DNP)	**237**	**571**
Namib-Naukluft Park		
Sandwich Harbour	15	35
Conception Bay	14	50
Meob	18	100
Sub-total (NNP)	**47**	**185**
Sperrgebiet National Park (SNP)		
Hottentots Bay	187	300
Guano Bay	0	1

Breeding colonies	**Minimum estimate**	**Maximum estimate**
Grosse Bucht	15	17
Possession Island	2	2
Elizabeth Bay	7	10
Marmora Pan	13	55
Chameis Pan	1	6
Sub-total (SNP)	**225**	**391**
Single pairs		
SNP	0	10
NNP	20	20
DNP and SCP	100	400
Sub-total (single pairs)	**120**	**430**
Sub-total (Namibia)	**930**	**2347**
SOUTH AFRICA		
Alexander Bay	15	30
Port Nolloth Pan	7	10
Oubeep Pan	3	6
Dreyerspan	2	20
Karaspan	2	16
Brandfontein	2	10
Struisbay	11	13
De Hoop	2	10
Gouritz	0	2
Cape Recife	1	1
Coega	3	5
Alexandria Dune Fields	17	25
Sub-total (South Africa)	**65**	**148**
Total estimated breeding pairs	**1001**	**2685**

Table 9.3: Previous and current population estimates of Damara Terns. Unless stated otherwise, the numbers represent individual breeding Damara Terns.

Source	Estimated Population			
	Global	Angola	Namibia	South Africa
Johnson and Frost (1978)	3000 (excl. Angola)	–	–	–
Clinning (1978)	3500–4000	–	2000	–
Brooke (1984)	–	–	–	*c.* 150 pairs
Collar and Stuart (1985)	1000–2000 pairs	–	–	–
Williams and Meyer (1986)	<4000	–	–	–
Braby *et al.* (1992)	7000 (20% juveniles)	1940 (including juveniles)	5755 (including juveniles)	
Simmons *et al.* (1998a)	13500	–	–	–
Barnes (2000)	–	–	–	120 pairs
Kemper *et al.* (2007)	930 pairs (excl. Angola)	–	–	–
Simmons (2010)	–	max. 190 pairs	–	–
This study	2002–5370 (1001–2685 breeding pairs)	12–280 (6–190 breeding pairs)	1860–4994 (930–2347 breeding pairs)	130–296 (65–148 breeding pairs)

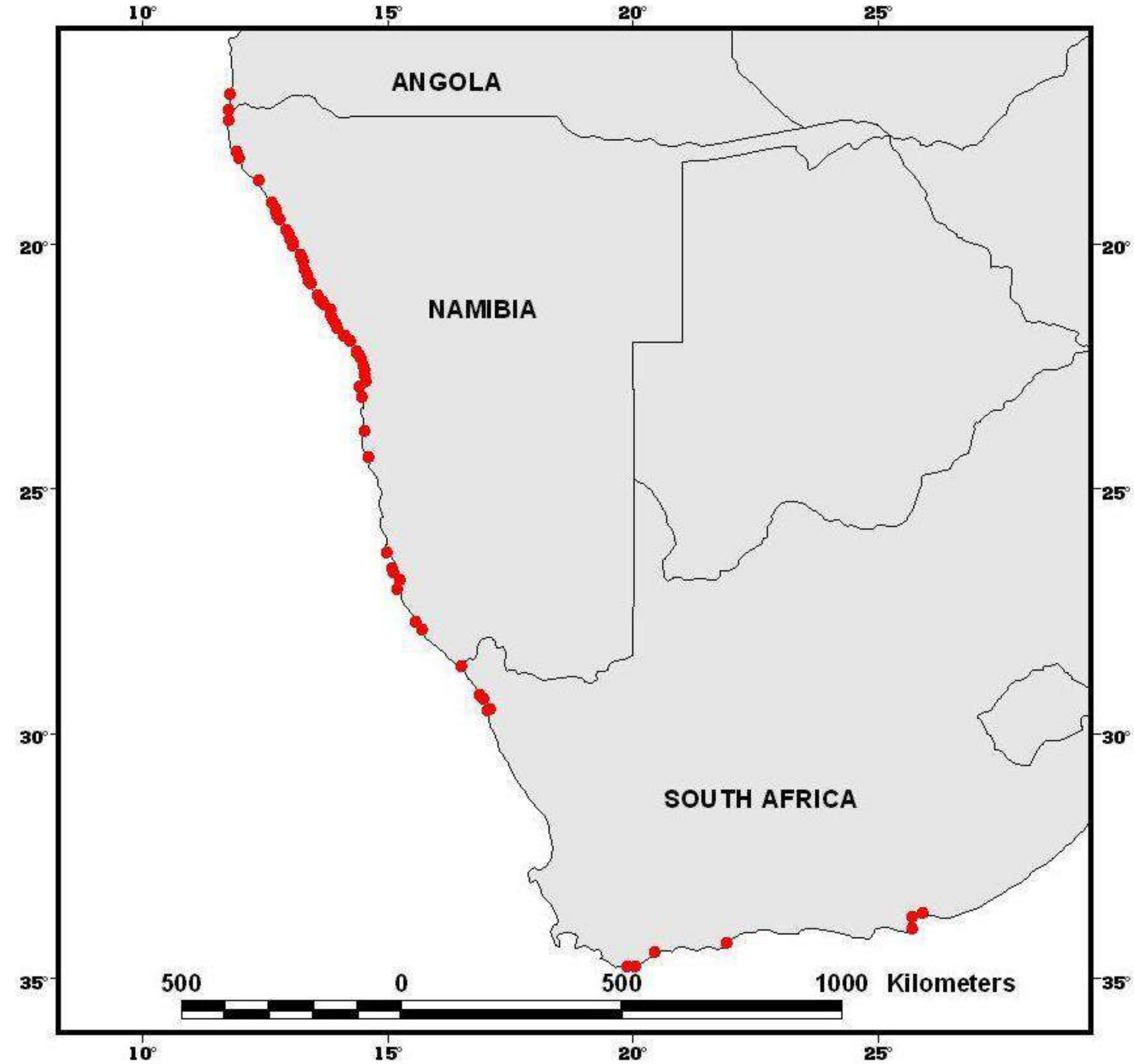


Figure 9.1: Distribution and location of all known Damara Tern breeding colonies in Angola, Namibia and South Africa.

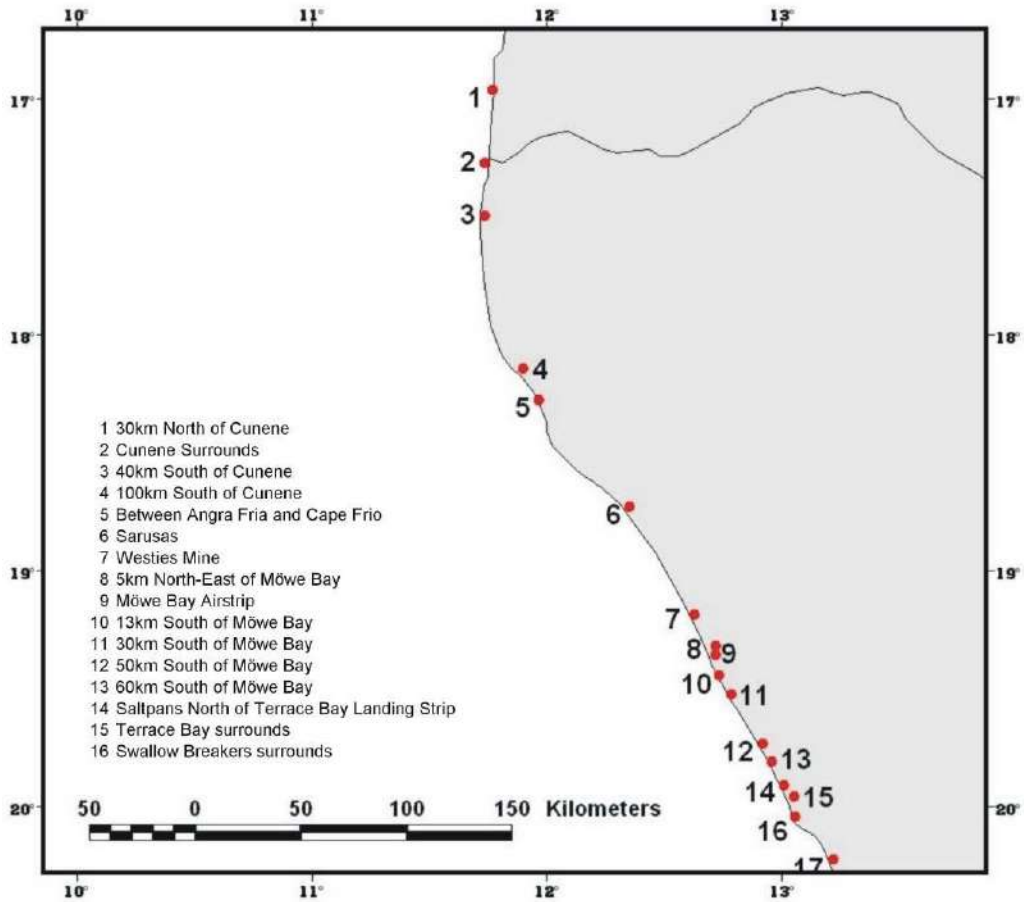


Figure 9.2: Distribution and location of Damara Tern breeding colonies in Angola and part of the Skeleton Coast Park, Namibia.

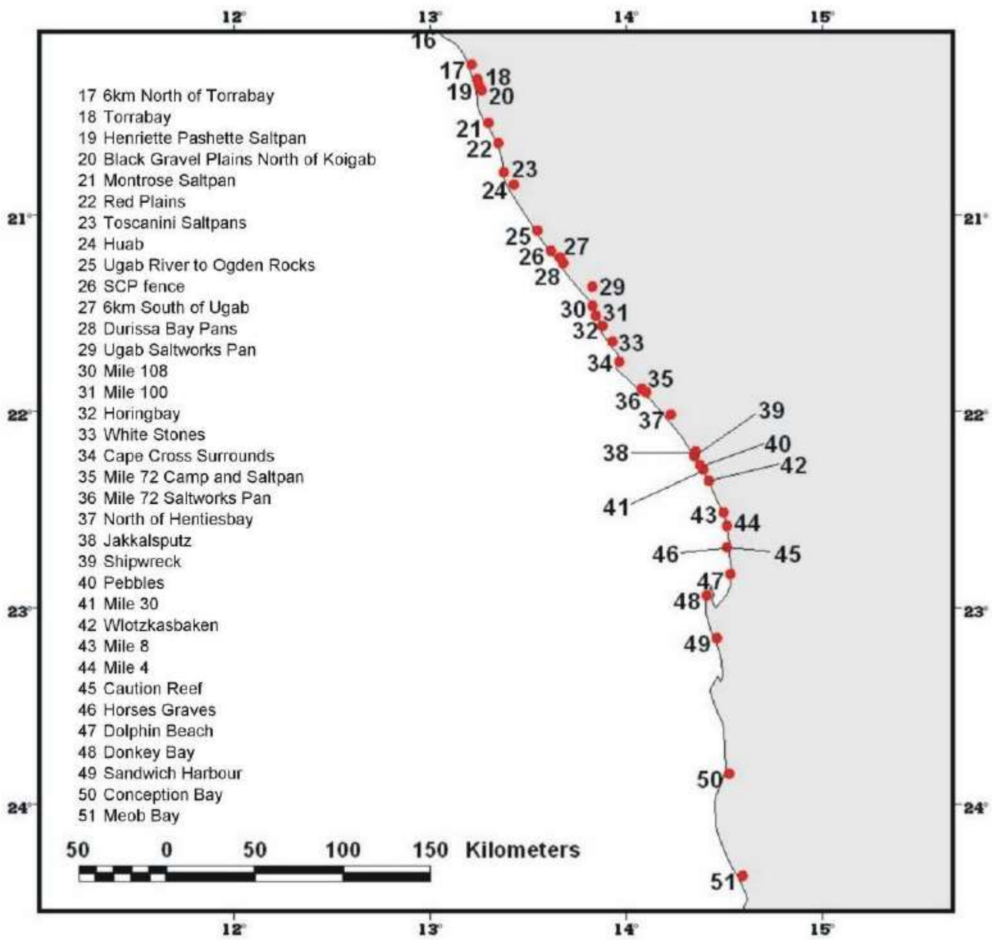


Figure 9.3: Distribution and location of all known Damara Tern breeding colonies in the southern part of the Skeleton Coast Park, the Dorob National Park, and the Namib Naukluft Park, Namibia.

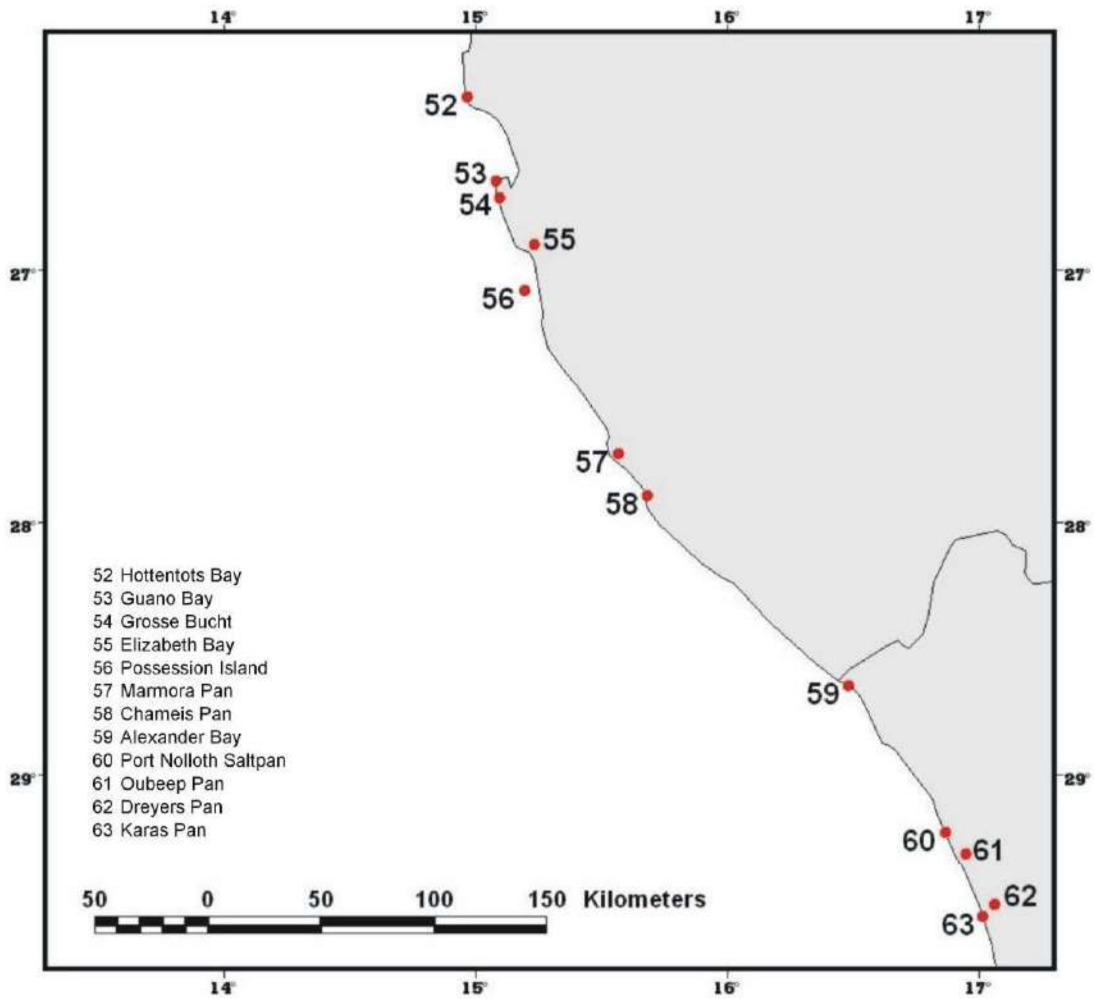


Figure 9.4: Distribution and location of all known Damara Tern breeding colonies in the Sperrgebiet National Park, Namibia and the Northern Cape, South Africa.

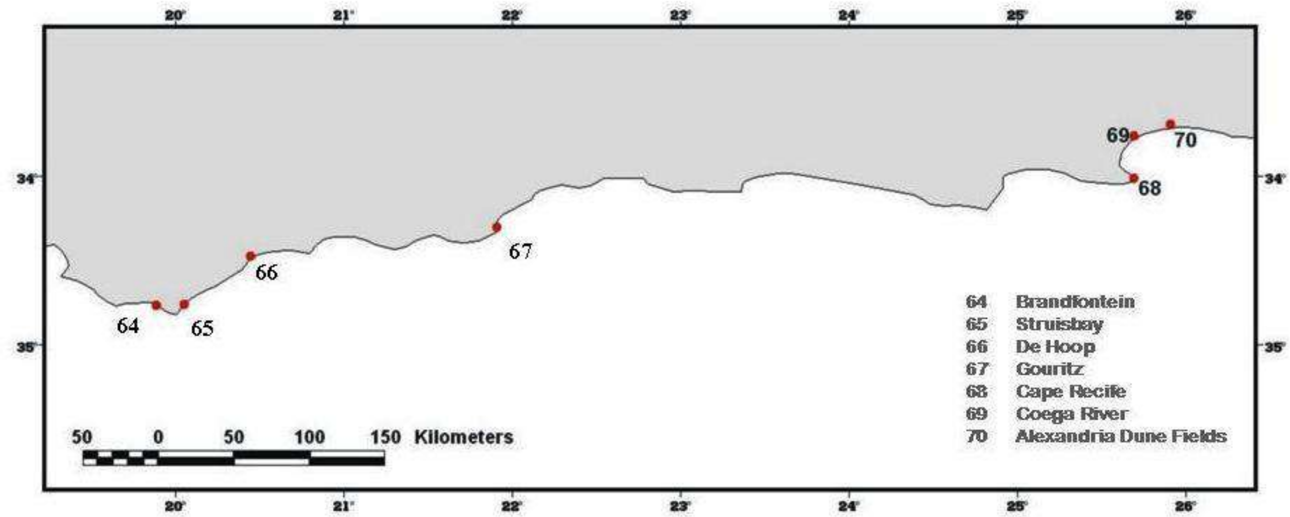


Figure 9.5: Distribution and location of all known Damara Tern breeding colonies in the Western and Eastern Cape, South Africa.

Chapter 10

Synthesis and recommendations


Kevin Jones

Synthesis and recommendations

Synthesis

The Damara Tern, with its scattered distribution in a barren desert mainland and its long distance migration to West Africa, remains an elusive species to study. This thesis used almost three decades of data collection, observations of the species in migratory countries like Nigeria, and observations of ecologically equivalent Peruvian Terns *Sterna lorata* in Chile. The study has provided new and updated information and greatly increased our knowledge base of the species. Its most important contributions include:

Chapter 1: A comparative description and review of all small terns using published information.

Chapters 2 and 3: New and detailed information of the breeding biology of Damara Terns for update of the description of the species;
including the evolution of the small clutch size, egg dimensions and masses, incubation and fledging periods, breeding success in Namibia and for individual colonies, chick hatching and fledging measurements, chick growth patterns and rate, and chick feeding rates.

Chapter 4: The first information on immature survival and age at first breeding of Damara Terns.

Chapter 5: The first information on annual breeding dispersal and adult survival of Damara Terns.

Chapter 6: 1. Overall prey capture success of Damara Terns at two colonies in southern Namibia, and descriptions of the effects of environmental variables on prey capture success.
2. The most detailed description of Damara Tern chick diet to date.

Chapter 7: The effect of diamond mining on feeding and breeding Damara Terns, especially the effect of increased turbidity as a result of sediment discharge into feeding grounds.

Chapter 8: The audit of conservation management at a Damara Tern colony in central Namibia negatively affected by off-road driving.

Chapter 9: 1. A new estimate of the breeding population and an account (and gazetteer) of all known breeding colonies in Angola, Namibia and South Africa (i.e. globally).
2. Recommended survey methods to improve and update population estimates.
3. A review of conservation measures enacted for breeding populations, and recommendations for future conservation.

Recommendations

Gaps in our knowledge

Because the Damara Tern remains a difficult and time-consuming species to study, gaps in our knowledge that could not be filled in my thesis due to insufficient data still remain. These include:

1. Data for energy content of prey fed to Damara Tern chicks to compare with the energy content of similar tern species. This information would be useful to understanding the small clutch size and slower chick growth rate of Damara Terns (Chapters 2, 3 and 6).
2. Energy allocations and activity budgets of Damara Tern chicks to investigate if more energy is spent on activity/movement in Damara Tern chicks than chicks of other small tern species. This information would also contribute to our understanding of slower growth rates of chicks (Chapter 3).
3. Further investigation into dispersal using increased study areas and including more colonies (Chapter 5). This would, however, be methodologically difficult due to the size of the area and the time needed.
4. The relationship of environmental variables, prey capture success and its effect on chick provisioning (feeding) rates (Chapters 6 and 7).
5. Increased information on diet of chicks, and a study of adult diet would help our understanding of important prey species, especially in light of predicted reductions in food availability as a result of climate change (Roux 2003) (Chapter 6).
6. An investigation of the effect of nest distance to sea on chick provisioning rates (Chapter 7).
7. A comparison of energy content of prey fed to chicks at different colonies to test whether energy content has an effect on body condition at these colonies (Chapter 7).
8. Surveys to assess the continued existence of colonies that were last visited prior to 2000 need to be undertaken. This is particularly the case for the colonies along the coast of South Africa (Chapter 9).
9. Up-to-date surveys of Damara Tern breeding populations are urgently needed to assess the size of the global breeding population more

accurately. This is necessary to re-evaluate the species' IUCN conservation status (Chapter 9).

10. Monitoring of breeding colonies adversely affected by off-road driving, especially colonies between Ugab River and Swakopmund (Plate 2).
11. An investigation into the trapping and eating/trading of Damara Terns in Angola and migratory countries and its effect on the global population (Annex 1).

Conservation Management

The conservation of breeding populations has already been discussed in detail in Chapter 9. However, the most important points will be re-iterated along with recommendations for protection of non-breeding populations of Damara Terns.

Breeding populations

The most effective approach regarding the protection of breeding populations is the protection and management of important breeding areas (Braby *et al.* 2001, Chapters 5, 8). Colonies that make up more than 1% of the breeding population should be protected from human disturbance.[1] Although at least 95% of the breeding population can be found in protected areas, their conservation remains difficult. This is mainly because human activities that create disturbances are still allowed in these areas (Chapter 9). For instance, Iona National Park in southern Angola is not effectively protected and illegal killing of protected species is ongoing there (T. de Wit pers. comm.). Mining occurs in every protected area along the coastline of Namibia. Although no direct evidence has suggested that mining has had detrimental effects on breeding Damara Terns, the possibility of finding profitable mining deposits at important colony sites may threaten breeding Damara Terns. Other disturbances as a result of mining include mining-related activities at feeding

[1] As part of the criteria for listing an area as an Important Bird Area (IBA, Fishpool *et al.* 1998).

grounds (for more detail see Chapter 9). Off-road driving, the seemingly biggest human disturbance, remains a problem, especially in the Dorob National Park (DNP) of Namibia. Only two colonies in the entire DNP have been cordoned off to protect breeding terns, and this method of protection has resulted in antagonism by off-road drivers. Cutting fences and traversing across breeding grounds remains a regular occurrence, even eight years after fences were first erected (pers. obs). The coastal area between Ugab River and Swakopmund has been detrimentally affected by off-road vehicles (Plate 2), and although permit systems are in place, enforcement has been weak and drivers are either unaware of or refuse to obey the regulations. With the recent proclamation of the Dorob National Park, greater restrictions will be enforced to regulate off-road drivers. Banning off-road driving on beaches and other sensitive areas had direct positive impacts on various seabirds in South Africa (Williams *et al.* 2004). Banning of off-road vehicles on the coast of Namibia would result in major opposition by the coastal community. However, without a decrease in destruction to the desert landscape and its biodiversity caused by off-road driving, it may have to be an eventual option to consider.

Non-breeding populations

The trapping and killing of Damara Terns in their migratory countries has been documented only recently (Braby 2010, Annex 1). The extent of this killing and its impact on the global population of Damara Terns is largely unknown. Virtually the entire population of Damara Terns cross these countries at least once a year, roosting and feeding along the coast. Therefore, it is likely that Damara Terns are significantly affected by this activity. Successful measures were put in place by the program “Save the Seashore Birds Project” to reduce similar activities in Ghana in the 1990s (Yaa Ntiamoa-Baidu 1990). These measures were three-fold, and included:

1. Research to better define the extent of these activities on tern populations.
2. Education and public awareness campaigns that led to the formation of Wildlife Clubs in Ghana to draw attention to the problem and encourage positive action.
3. Legislation that put all terns on Ghana's list of protected species and also gave legal backing to re-enforce protection action.

If human livelihoods are, to some extent, dependent on the trapping of seabirds, then alternative avenues of income acquisition need to be explored for communities involved. Ghana had large success in reducing these activities (Yaa Ntiamoa-Baidu 1990), and similar initiatives should be conducted in all affected countries. Ultimately there should be an integrated and holistic approach led by all migratory countries in West Africa.

Conclusion

This thesis presents information that highlights the importance of an integrated approach to conservation that includes the protection of important breeding (and feeding) sites, and the protection of migrating Damara Terns along the West African coastline. The proclamation of national parks in coastal Namibia and southern Angola is a major step illustrating the commitment made by governments towards the protection of species like the Damara Tern. However, without effective enforcement and awareness, national parks are merely deemed 'paper parks' and are not fulfilling their mandate toward the conservation of biodiversity. Enforcement is needed to implement the legal restrictions set out by park rules, and increased awareness and education is vital in order to shed light on why these restrictions are necessary.

Reference List

Reference List

Abrahams M and Kattenfeld M. 1997. The role of turbidity as a constraint on predator-prey interactions in aquatic environments. Behavioural Ecology and Sociobiology 40:169–174.

Ainley DG. 1977. Feeding methods in seabirds: a comparison of polar and tropical nesting communities in the eastern Pacific Ocean. Pp 669–685 *in* Adaptations within Antarctic ecosystems (Llano GA, ed.). Smithsonian Institution Press, Washington, D.C.

Ainley DG, Spear LB and Boekelheide RJ. 1986. Extended post-fledging care in the Red-tailed Tropicbird and Sooty Tern. Condor 88:101–102.

Akçakaya HR, Atwood JL, Breininger D, Collins CT and Duncan B. 2003. Metapopulation dynamics of the California Least Tern. Journal of Wildlife Management 67:829–842.

Altwegg R, Crawford RJM, Underhill LG, Martin AP and Whittington PA. 2007. Geographic variation in reproduction and survival of Kelp Gulls *Larus dominicanus* in southern Africa. Journal of Avian Biology 38:580–586.

Andersson CJ. 1872. Birds of Damaraland. Va Voorst, London.

Ashmole NP and Tovar HS. 1968. Prolonged parental care in Royal Terns and other birds. Auk 85:90–100.

Ashmole NP. 1971. Seabird ecology and the marine environment. Pp 223–286 *in* Avian Biology (Volume 1, Farner D S and King JR, eds). Academic Press, London.

Atwood JL and Kelly PR. 1984. Fish dropped on breeding colonies as indicators of Least Tern food habits. The Wilson Bulletin 96:34–47.

Atwood JL and Massey BW. 1988. Site fidelity of Least Terns in California. Condor 90:389–394.

Austin OL. 1940. Some aspects of individual distribution in the Cape Cod tern colonies. Bird-Banding 11:155–169.

Austin OL. 1949. Site tenacity, a behaviour trait of the Common Tern *Sterna hirundo*. Bird-Banding 20:1–39.

Babatunde MA. 2009. Global economic slowdown and the African continent: Re-thinking export-led growth. International Journal of African Studies 2:47–73.

Baptist MJ and Leopold MF. 2010. Prey capture success of Sandwich Terns *Sterna sandvicensis* varies non-linearly with water transparency. Ibis 152:815–825.

Barnard P (ed.). 1998. Biological Diversity in Namibia – a country study. Namibian National Biodiversity Task Force, Windhoek.

Barnes KN (ed.). 2000. The Eskom Red Data Book of birds in South Africa, Lesotho and Swaziland. BirdLife South Africa, Johannesburg.

Beadell JS, Schreiber AE, Schreiber RW, Schenk GA and Doherty PF. 2003. Survival of Brown Boobies *Sula leucogaster* at Johnston Atoll: A long-term study. Auk 120:811–817.

Becker PH and Specht R. 1991. Body mass fluctuations and mortality in Common Tern *Sterna hirundo* chicks dependant on weather and tide in the Wadden Sea. Ardea 79:45–56.

Becker PH, Frank D and Sudmann SR. 1993. Temporal and spatial pattern of Common Tern *Sterna hirundo* foraging in the Wadden Sea. Oecologia 93:389–393.

Becker PH and Wendeln H. 1997. A new application for transponders in population ecology of the Common Tern. Condor 99:534–538.

Becker PH, Wendeln H and Gonzalez-Solis J. 2001. Population dynamics, recruitment, individual quality and reproductive strategies in Common Terns *Sterna hirundo* marked with transponders. Ardea 2001:241–252.

Blockpoel H and Courtney P. 1980. Site tenacity in a new Ring-billed Gull colony. Journal of Field Ornithology 51:1–5.

Bogliani GM, Fasola M, Canova L and Saino N. 1992. Foraging rhythm and chick diet in Little Terns in three Adriatic coastal wetlands. Avocetta 16:31–34.

Bolton M. 1991. Determinants of chick survival in the Lesser Black-Backed Gull: Relative contributions of egg size and parental quality. Journal of Animal Ecology 60:949–960.

Borrow N and Demey R. 2001. Birds of Western Africa. Christopher Helm, London.

Bourdillon BH. 1944. Terns on Lagos Beach, Nigeria. Ibis 86:405–407.

Boyer D, Cole J and Bartholome C. 2000. Southwestern Africa: Northern Benguela Current region. Marine Pollution Bulletin 41:123–140.

Boyer DC, Boyer H, Fossen I and Kreiner A. 2001. Changes in abundance of the Northern Benguela sardine stock during the decade 1999–2000, with comments on the relative importance of fishing and the environment. South African Journal of Marine Science 23:67–84.

Braby RJ, Braby SJ and Simmons RE. 1992. 5000 Damara terns in the northern Namib Desert. A reassessment of world population numbers. Ostrich 63:133–135.

Braby RJ. 1995. Effects of human disturbance on Damara Tern breeding success in the central Namib. Unpublished Report, Ministry of Environment and Tourism, Swakopmund, Namibia.

Braby RJ, Shapira A and Simmons RE. 2001. Successful conservation measures and new breeding records for Damara Terns *Sterna balaenarum* in Namibia. Marine Ornithology 28:81–84.

Braby J. 2010. New migration records for the Damara Tern *Sterna balaenarum*. Ornithological Observations 1:38–41.

Branch GM, Barkai A, Hockey PAR and Hutchings L. 1987. Biological interactions: causes and effects of variability in the Benguela Ecosystem? South African Journal of Marine Science 5:425–445.

Brenninkmeijer AE, Stienen WM, Klaassen M and Kersten M. 2002. Foraging ecology of wintering terns in Guinea-Bissau. Ibis 144:602–613.

Breton AR, Diamond AW and Kress SW. 2006. Encounter, survival and movement probabilities from an Atlantic Puffin *Fratercula arctica* metapopulation. Ecological Monographs 76:133–149.

Bridge ES, Jones AW and Baker AJ. 2005. A phylogenetic framework for the terns (Sternini) inferred from mtDNA sequences: implications for taxonomy and plumage evolution. Molecular Phylogenetics and Evolution 35:459–469.

Brooke RK. 1981. The seabirds of Moçàmedes Province, Angola. Gerfaut 71:209–225.

Brooke RK. 1984. South African Red Data Book – birds. South Africa National Science Progress Report, No 97, CSIR, Pretoria.

Brown RGB. 1979. Seabirds of the Senegal upwelling and adjacent waters. Ibis 121:283–121.

Brunton DH. 1997. Impacts of predators: Center nests are less successful than edge nests in a large nesting colony of Least Terns. Condor 99:322–380.

Burger J. 1974. Breeding adaptations of Franklin's Gull *Larus pipixcan* to a marsh habitat. Animal Behaviour 22:521–567.

Burger J. 1980. The transition to independence and postfledging parental care in seabirds. Pp 367–447 *in* Behavior of Marine Animals (Burger J, Olla B and Winn H, eds). Plenum Press, New York.

Burger J. 1982. Jamaica Bay Studies: I. Environmental determinants of abundance and distribution of Common Terns *Sterna hirundo* and Black Skimmers *Rynchops niger* at an east coast estuary. Colonial Waterbirds 5:148–160.

Burger J and Gochfeld M. 1986. Age differences in foraging efficiency of American Avocets. Bird Behaviour 6:66–71.

Burnham KP and Anderson DR. 2002. Model selection and multimodel inference: A practical information-theoretic approach. Second Edition. Springer, New York.

Cade BS and Noon BR. 2003. A gentle introduction to quantile regression for ecologists. Frontiers in Ecology and the Environment 1:412–420.

Cairns WE. 1982. Biology and behaviour of breeding Piping Plovers. Wilson Bulletin 94:531–545.

Catry T, Ramos JA, Catry I, Allen-Revez M and Grade N. 2004. Are salinas a suitable alternative breeding habitat for Little Terns *Sterna albifrons*? Ibis 146:247–257.

Catry T, Ramos JA, Martins J, Peste F, Trigo S, Paiva VH, Almeida A, Luis A, Palma J and Andrade PJ. 2006. Intercolony and annual differences in the diet and feeding ecology of Little Tern adults and chicks in Portugal. Condor 108: 366–376.

Chabrzyk G and Coulson JC. 1976. Survival and recruitment in the Herring Gull *Larus argentatus*. Journal of Animal Ecology 45:187–203.

Clark BM, Smith CE and Meyer WF. 1998. Ecological effects of fine tailings and marine diamond pumping operations on surf zone fish assemblages near Lüderitz, Namibia. Anchor Consultants Report No.1009/2 to Namdeb Diamond Corporation.

Clark BM. 2006. Climate change: a looming challenge for fisheries management in southern Africa. Marine Policy 30:84.

Clinning CF. 1978. The biology and conservation of the Damara Tern in South West Africa. Madoqua 11:31–39.

Cody ML. 1966. A general theory on clutch size. Evolution 20:174–184.

Colbert J, Lebreton JD, Allaine D, and Gaillard JM. 1994. The estimation of age-specific breeding probabilities from recaptures or resightings in vertebrate populations: II. Longitudinal models. Biometrics 50:375–387.

Colbert J, Danchin E, Dhondt AA and Nichols JD. 2001. Dispersal. Oxford University Press, New York.

Collar NJ and Stuart SN. 1985. The threatened birds of Africa and related islands. The ICBP/IUCN Red Data Book. Cambridge University Press, Cambridge.

Congleton RD. 2009. On the political economy of the financial crisis and bailout of 2008–2009. Public Choice 140:287–317.

Connor MA. 1980. Development of energy and mineral resources and its effect on bird conservation in southern Africa. Proceedings of the IV Pan-African Ornithological Congress 389–406.

Conover MR and Miller DE. 1978. Reactions of Ring-billed Gulls to predators and human disturbances at their breeding colonies. Colonial Waterbirds 2:41–47.

Coulson JC and White E. 1958. The effect of age on the breeding biology of Kittiwake. Ibis 100:40–51.

Coulson JC and Horobin J. 1976. The influence of age on the breeding biology and survival of the Arctic Tern *Sterna paradisaea*. Journal of Zoology 178:247–260.

Cramp S, Bourne WRP and Saunders DR. 1974. The seabirds of Britain and Ireland. Collins, London.

Cramp S and Simmons KEL. 1983. The birds of the Western Palearctic. Volume 4. Oxford University Press, Oxford.

Cramp S. 1985. Handbook of the Birds of Europe, the Middle East and North Africa. Volume 4. Oxford University Press, New York.

Crawford RJM and Simmons RE. 1997. Damara Tern *Sterna baleanarum*. Pp 480–481 *in* The atlas of southern African birds (Harrison JA, Allan DG, Underhill LG, Herremans M, Tree AJ and Brown CJ, eds). BirdLife South Africa, Johannesburg.

Crawford RJM, Goya E, Roux J-P and Zavalaga CB. 2006. Comparison of assemblages and some life-history traits of seabirds in the Humboldt and Benguela Systems. African Journal of Marine Science 28:553–560.

Crawford RJM, Whittington PA, Martin AP, Tree AJ and Makhado AB. 2009. Population trends of seabirds breeding in South Africa's Eastern Cape and the possible influence of anthropogenic and environmental change. Marine Ornithology 37:159–174.

Crespin L, Harris MP, Lebreton JD, Frederiksen M and Wanless S. 2006. Recruitment to a seabird population depends on environmental factors and on population size. Journal of Animal Ecology 75:228–238.

CSIR. 1996. Elizabeth Bay monitoring project 1995 review. CSIR Report. ENV/S-96066.

CSIR. 1997. Elizabeth Bay monitoring project 1996 review. CSIR Report. ENV/S-97153.

CSIR. 1998. Elizabeth Bay monitoring project 1997 review. CSIR Report. ENV/S-98049.

Cushing DH. 1971. Upwelling and the production of fish. Advances in Marine Biology 9:255–334.

Danchin E, Cadiou B, Monnat J-Y and Rodriguez Estrella R. 1991. Recruitment in longlived birds: conceptual framework and behavioural mechanism. Acta XX Congressus Internationalis Ornithologici 1641–1656.

Davies S.1981. Development and behaviour of Little Tern chicks. British Birds 74:291–298.

Day RH, Prichard AK and Nigro DA. 2003. Ecological specialization and overlap of *Brachyramphus murrelets* in Prince William Sound, Alaska. Auk 120:680–699.

de Villiers D and Simmons RE. 1997. The high incidence and origin of two-egg clutches in a Damara Tern colony in south-western Namibia. Madoqua 19:111–113.

DiConstanzo J. 1980. Population dynamics of a Common Tern colony. Journal of Field Ornithology 51:229–243.

Dunn EK.1972. Effect of age on the fishing ability of Sandwich terns *Sterna sandvicensis*. Ibis 114:360–366.

Dunn EK.1973. Changes in fishing ability of terns associated with wind speed and sea surface conditions. Nature 244:520–521.

Dunn EK. 1975. The role of environmental factors in the growth of tern chicks. Journal of Animal Ecology 44:743–754.

Durant JM, Crawford RJM, Wolfaardt AC, Agenbag K, Visagie J, Upfold L and Stenseth N. 2010. Influence of feeding conditions on breeding African Penguins – importance of adequate local food supplies. Marine Ecology Progress Series 420:263–271.

Elgood JH, Fry CH and Dowsett RJ. 1973. African migrants in Nigeria. Ibis 115:1–45.

Elliot ML, Hurt R and Sydeman WJ. 2007. Breeding biology and status of the California Least Tern *Sterna antillarum browni* at Alameda Point, San Francisco Bay, California. Waterbirds 30:317–454.

Erwin RM. 1977. Foraging and breeding adaptations to different food regimes in three seabirds: the Common Tern *Sterna hirundo*, Royal Tern *Sterna maxima* and Black Skimmer *Rynchops niger*. Ecology 58:389–397.

Escalante R. 1970. The Yellow-billed Tern *Sterna superciliaris* in Uruguay. Auk 87:574–577.

Every B. 1979. Damara Tern in Eastern Cape. Bee-eater 30(1):1–2.

Feare CJ. 1975. Post-fledging parental care in Crested and Sooty Terns. Condor 77:368–370.

Finney SK, Harris MP, Keller LF, Elstron DA, Monaghan P and Wanless S. 2003. Reducing the density of breeding gulls influences the pattern of recruitment of immature Atlantic Puffins *Fratercula arctica* to a breeding colony. Journal of Applied Ecology 40:545–552.

Frank D. 1992. The influence of feeding conditions and food provisioning of chicks in Common Terns *Sterna hirundo* nesting in the German Wadden Sea. Ardea 80:45–55.

Frank D and Becker PH. 1992. Body mass and nest reliefs in Common Terns *Sterna hirundo* exposed to different feeding conditions. Ardea 80:57–69.

Frost PGH and Shaughnessy G. 1976. Breeding adaptations of the Damara Tern *Sterna balaenarum*. Madoqua 9(3):33–39.

Frost P and Johnson P. 1977. Seabirds on the Diamond Coast, South West Africa, December 1976. Cormorant 3:13.

Fujita G, Totsu K, Shibata E, Matsuoka Y, Morita H, Kitamura W, Kuramoto N, Masuda N and Higuchi H. 2009. Habitat management of Little Terns in Japan's highly developed landscape. Biological Conservation 142:1891–1898.

GenStat Committee. 2009. The guide to GenStat release 12. VSN International, Hemel Hemstead.

Giess W. 1968. A short report on the vegetation of the Namib coastal area from Swakopmund to Cape Frio. Dintera 1:13–29.

Gill RE and Mewaldt LR. 1983. Pacific Coast Caspian Terns: dynamics of an expanding population. Auk 100:369–381.

Gochfeld M and Burger J. 1996. Family Sternidae (terns). Pp 624–667 *in* Handbook of the birds of the world (Volume 3, del Hoyo J, Elliot A, and Sargata A, eds). Lynx Editions, Barcelona.

Gore JA and Kinnison MJ. 1991. Hatching success in roof and ground colonies of Least Terns. Condor 93:759–762.

Günster A. 1995. Grass cover distribution in the central Namib – a rapid method to assess regional and local rainfall patterns of arid regions? Journal of Arid Environments 29:107–114.

Gyory J, Mariano AJ and Ryan EH. 2009. The Benguela Current. Ocean Surface Currents. http://oceancurrents.rsmas.miami.edu/atlantic/benguela.html Last accessed 15 October 2010.

Haney JC and Stone AE. 1988. Seabird foraging tactics and water clarity: are plunge divers really in the clear? Marine Ecology Progress Series 49:1–9.

Harrington BA. 1974. Colony visitation behavior and breeding ages of Sooty Terns *Sterna fuscata*. Bird-Banding 45:115–144.

Harris MP, Wanless S and Rothery P. 2000. Adult survival rates of Shag *Phalacrocorax aritotelis*, Common Guillemot *Uria aalgae*, Razorbill *Alca torda*, Puffin *Fratercula arctica* and Kittiwake *Rissa tridactyla* on the Isle of May, 1986–1996. Atlantic Seabirds 2:133–150.

Harrison P. 1983. Seabirds: an identification guide. Croom Helm Ltd, Kent.

Hawksley O. 1950. A study of the behaviour and ecology of the Arctic Tern *Sterna paradisaea*. PhD Thesis, Cornell University, Ithaca.

Hawksley O. 1957. Ecology of the breeding population of Arctic Terns. Bird Banding 28:57–92.

Henkel LA 2006. Effect of water clarity on the distribution of marine birds in nearshore water of Monterey Bay, California. Journal of Field Ornithology 77:151–156.

Higgins PT and Davies SJF. 1996. Handbook of Australian, New Zealand and Antarctic Birds. Volume 3. Oxford University Press, Melbourne.

Hockey PAR and Wilson WA. 2003. Reproductive traits of marine terns (Sternidae): evidence for food limitation in the tropics? Ostrich 74:110–116.

Holloway M. 1993. The variable breeding success of the Little Tern *Sterna albifrons* in south-east India and protective measures needed for its conservation. Biological Conservation 65:1–8.

Holm KJ and Burger AE. 2002. Foraging behaviour and resource partitioning by diving birds during winter in areas of strong tidal currents. Waterbirds 25:312–325.

Hulsman K. 1976. The robbing behaviour of terns and gulls. Emu 76:143–149.

Hulsman K, Langham NPE and Blühdorn D. 1989. Factors affecting the diet of Crested Terns *Sterna bergii*. Australian Wildlife Research 16:475–489.

IUCN. 1992. Angola – environmental status quo assessment report. IUCN Regional Office for southern Africa, Harare.

IUCN. 2000. Red list categories and criteria version 3.1. IUCN Council, Gland.

IUCN. 2009. Summary statistics for globally threatened species. www.iucnredlist.org/ Last accessed 6 August 2010.

Johnson P. 1979. Third census of the Damara Tern at Elizabeth Bay, South West Africa, December 1978. Cormorant 7:32.

Kemper J, Underhill LG, Crawford RJM and Kirkman SP. 2007. Revision of the conservation status of seabirds and seals breeding in the Benguela ecosystem. Pp 325–342 *in* Final report of the BCLME (Benguela Current Large Marine Ecosystem) project on top predators as biological indicators of ecosystem change in the BCLME (Kirkman SP, ed.). Avian Demography Unit, Cape Town.

Kinahan J and Kinahan J. 2002. Baseline environmental assessment of Hottentot Bay on the Sperrgebiet coast of Namibia. Volume 1. Report for Hottentot Bay Investments cc, QRS Report 38.

Kirkman SP, Oosthuizen WH, Meyer MA, Kotze PGH, Roux JP and Underhill LG. 2007. Making sense of censuses and dealing with missing data: trends in pup counts of Cape Fur Seals *Arctocephalus pusillus pusillus* for the period 1972–2004. African Journal of Marine Science 29:161–176.

Kirsch EM. 1996. Habitat selection and productivity of Least Terns on the Lower Platte River, Nebraska. Wildlife Monographs 132:3–48.

Koenen MT, Utych RB and Leslie DM. 1996. Methods used to improve Least Tern and Snowy Plover nesting success on alkaline flats. Journal of Field Ornithology 67:281–291.

Koenker R and Bassett G. 1978. Regression quantiles. Econometrica 46:33–50.

Konarzewski M, Taylor JRE and Gabrielsen GW. 1993. Chick energy requirements and adult energy expenditures of Dovekies *Alle alle*. Auk 110:343–353.

Lack D. 1954. The natural regulation of animal numbers. Clarendon Press, Oxford.

Lack D. 1967. Interrelationships in breeding adaptation as shown by marine birds. Proceedings of the 14th International Ornithological Congress 3–42.

Lack D. 1968. Ecological adaptations for breeding in birds. Methuen, London.

le Roux J. 2006. The Swift Tern *Sterna bergii* in Southern Africa: growth and movement. Masters Thesis, University of Cape Town, Cape Town.

Lebreton JD, Burnham KP, Clobert J and Anderson DR. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs 62:67–118.

Lebreton JD, Hines JE, Pradel R, Nichols JD and Spendelow JA. 2003. Estimation by capture-recapture of recruitment and dispersal over several sites. Oikos 101:253–264.

Lemmetyinen R. 1972. Growth and mortality in the chicks of Arctic Terns in the Kougsfjord area, Spitzbergen in 1970. Ornis Fenninca 49:45–53.

Lima SL. 1987. Clutch size in birds: a predation perspective. Ecology 68:1062–1070.

Lubbe A. 2008. Condition indices for African Penguins. BSc Honours thesis, Department of Zoology, University of Cape Town, Cape Town.

Ludynia K and Kemper J. 2010. The first Namibian Islands' Marine Protected Area: a conservation measure for endangered seabirds in the Benguela Upwelling System. First World Seabird Conference, Victoria, Canada.

Martin TE. 1992. Interaction of nest predation and food limitation in reproductive strategies. Current Ornithology 9:163–197.

Martin TE. 1996. Life history evolution in tropical and south temperate birds: what do we really know? Journal of Avian Biology 27:263–272.

Martin P and Taylor A. 2002. First breeding of Damara Tern at Cape Recife. Bee-eater 53:11.

Massey BW. 1974. Breeding biology of the California Least Tern. Proceedings of the Linnaean Society of New York 72:1–24.

Massey BW and Atwood JL. 1981. Second-wave nesting of the California Least Tern: age composition and reproductive success. Auk 98:546–605.

Massey BW, Bradley DW and Atwood JL. 1992. Demography of a California Least Tern colony including effects of the 1982–1983 El Niño. Condor 94:976–983.

Mayfield H. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255–261.

Mayfield HF. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456–466.

McCullagh P and Nelder JA. 1989. Generalized Linear Models. Second Edition. Chapman and Hall, London.

McLachlan GR and Liversidge R.1970. Roberts Birds of South Africa. Third Edition. John Voelcker Bird Book Fund, Johannesburg.

McNicholl MK. 1975. Larid site tenacity and group adherence in relation to habitat. Auk 92:98–104.

McPeek MA and Holt RD. 1992. The evolution of dispersal in spatially and temporally varying environments. American Naturalist 140:1010–1027.

Mendelsohn J, Jarvis A, Roberts C and Robertson T. 2003. Atlas of Namibia : a portrait of the land and its people. Ministry of Environment and Tourism of Namibia, David Philip, Cape Town.

Molloy F. 2003. Coastal environment. Pp 25–29 *in* Namibia's marine environment (Molloy F and Reinikainen T, eds) Directorate of Environmental Affairs of the Ministry of Environment and Tourism, Namibia.

Monaghan P, Uttley JD, Burns MD, Thaine C and Blackwood J. 1989. The Relationship between food supply, reproductive effort and breeding success in Arctic Terns *Sterna paradisaea*. Journal of Animal Ecology 58:261–274.

Mundkur T. 1992. Breeding by one-year-old River Terns. Colonial Waterbirds 15:144–147.

Murray BG. 1994. Effect of selection for successful reproduction on hatching synchrony and asynchrony. Auk 111:806–813.

NACOMA. 2008. Namibia Coastal/Marine Bird Action Plan. Proceedings of a workshop on 1 April 2008. Swakopmund, Namibia.

Namdeb. 2003. Elizabeth Bay Mine Extension: Environmental Impact Assessment and Environmental Management Programme Report. Namdeb, Oranjemund.

Newton I. 1998. Population limitation in birds. Academic Press, London.

Nisbet ICT. 1978. The dependence of fledging success on egg size, parental performance and egg composition in Common and Roseate Terns *Sterna hirundo* and *S. dougalli*. Ibis 120:207–215.

Nisbet ICT and Cam E. 2002. Test for age-specific survival of the Common Tern. Journal of Applied Statistics 29:65–83.

Norman RK and Saunders DR. 1969. Status of Little Terns in Great Britain and Ireland in 1967. British Birds 62:4–13.

Ntiamoa-Baidu Y. 1990. Coastal wetlands conservation: the Save the Seashore Birds Project. Pp 91–95 *in* Living with wildlife: Wildlife resource management with local participation in Africa (Kiss A, ed.). The World Bank, Washington. World Bank Technical Papers 130: 1–217.

Oro D and Furness RW. 2002. Influences of food availability and predation on survival of kittiwakes. Ecology 83:2516–2528.

Paiva VH, Ramos JA, Machado D, Penha-Lopes G, Bonsala MF, Dias N and Nielsen S. 2006a. Importance of marine prey to growth of estuarine tern chicks: evidence from an energetic balance model. Ardea 94:241–255.

Paiva VH, Ramos JA, Catry T, Pedro P, Madeiros R and Palma J. 2006b. Influence of environmental factors and energetic value of food on Little Tern *Sterna albifrons* chick growth and food delivery. Bird Study 53:1–11.

Paiva VH, Ramos JA, Martins J, Almeida A and Carvalho A. 2008. Foraging habitat selection by Little Terns *Sterna albifrons* in an estuarine lagoon system of southern Portugal. Ibis 150:18–31.

Payne RW, Murray DA, Harding SA, Baird DB and Souter DM.. 2005. Genstat for Windows (8th edition). Oxford, VSN International.

Pallet J. 1995. The Sperrgebiet, Namibia's least known wilderness. Desert Research Foundation of Namibia and Namdeb, Windhoek.

Peste F, Trigo S and Luis A. 2004. Foraging behaviour of breeding Little Tern *Sterna albifrons* at Ria de Aveiro. Airo 14:55–62.

Peterson RG and Stramma L. 1991. Upper-level circulation in the South Atlantic Ocean. Progress in Oceanography 26:1–73.

Pons JM and Migot P. 1995. Life-history strategy of the Herring Gull: changes in survival and fecundity in a population subjected to various feeding conditions. Journal of Animal Ecology 64:592–599.

Prévot-Julliard AC, Lebreton JD and Pradel R. 1998. Re-evaluation of adult survival of Black-headed Gulls *Larus ridiburdus* in presence of recapture heterogeneity. Auk 115:85–95.

Pulfrich A, Parkins CA, Branch GM, Bustamante RH and Velasques CR. 2003. The effects of sediment deposits from Namibian diamond mines on inter-tidal and sub-tidal reefs and rock-lobster populations. Aquatic Conservation: Marine Freshwater Ecosystems 13:233–255.

Randall RM and McLachlan A. 1982. Damara Terns breeding in the Eastern Cape, South Africa. Ostrich 53:50–51.

Reed JM and Oring LW. 1993. Philopatry, site fidelity, dispersal, and survival of Spotted Sandpipers. Auk 110:541–551.

Reiss L, Kruger LA. 1998. Monitoring of the Damara Tern *Sterna balaenarum* near Swakopmund, Namibia during the 1997/98 breeding season. Unpublished Report, Ministry of Environment and Tourism, Swakopmund, Namibia.

Reiss MJ. 1989. The allometry of growth and reproduction. Cambridge University Press, Cambridge.

Renken RB and Smith JW. 1995a. Annual adult survival of interior Least Terns. Journal of Field Ornithology 66:112–116.

Reuken RB and Smith JW. 1995b. Interior Least Tern site fidelity and dispersal. Colonial Waterbirds 18:193–198.

Ricklefs RE. 1979. Adaptation, constraint and compromise in avian postnatal development. Biological Reviews 54:269–280.

Ricklefs RE. 1983. Some considerations on reproductive energetics of pelagic seabirds. Studies on Avian Biology 8:84–94.

Ricklefs RE. 1992. Seabird life-histories and the marine environment: some speculations. Colonial Waterbirds 13:1–6.

Ricklefs RE and White SC. 1981. Growth and energetics of the Sooty Tern *Sterna fuscata* and Common Tern *Sterna hirundo*. Auk 98:361–378.

Robinson JA and Oring LW. 1997. Natal and breeding dispersal of American Avocets. Auk 114:416–430.

Roux J-P. 2003. Risks. Pp 137–152 *in* Namibia's marine environment (Molloy, F and Reinikainen T, eds). Directorate of Environmental Affairs of the Ministry of Environment and Tourism, Windhoek, Namibia.

Safina C and Burger J. 1988. Ecological dynamics among prey fish, bluefish, and foraging Common Terns in an Atlantic coastal system. Pp 93–165 *in* Seabirds and other marine vertebrates: competition, predation, and other interactions (Burger J, ed.). Columbia University Press, New York..

Safriel UN. 1975. On the significance of clutch size in nidifugous birds. Ecology 56:703–708

Sakko AL. 1998. The influence of the Benguela Upwelling System on Namibia's marine biodiversity. Biodiversity and Conservation 7:419–433.

Sandvik H, Erisktad KE, Fauchald P and Tveraa T. 2008. High survival of immatures in a long-lived seabird: insights from a long-term study of Atlantic Puffin. Auk 125:723–730.

Schneider G. 2009. Treasures of the diamond coast: A century of diamond mining in Namibia. Macmillian Education Namibia Publishers, Windhoek.

Shannon LV. 1985. The Benguela Ecosystem: I. Evolution of Benguela, physical features and processes. Oceanography and Marine Biology 23:105–182.

Shannon LV. 1989. The physical environment. Pp 12–27 *in* Oceans of Life off Southern Africa (Payne AIL and Crawford RJM, eds). Vlaeberg Publishers, Cape Town.

Schoener TW and Schoener A. 1978. Estimating and interpreting body-size growth in some *Anolis* lizards. Copeia 3:390–405.

Siegfried WR and Johnson P. 1978. The Damara Tern and other seabirds on the Diamond Coast , South West Africa, December 1977. Cormorant 3:13.

Siegfried WR, Frost PGH, Cooper J and Kemp AC. 1976. South African Red Data Book- Aves. South African National Scientific Programmes Report No 7. Council for Scientific and Industrial Research, Pretoria.

Silverman BW. 1986. Density estimation for statistics and data analysis. Chapman and Hall, London.

Simmons KEL. 1953. Some aspects of the aggressive behaviour of three closely related plovers (Charadrius). Ibis 95:115–127.

Simmons RE. 1993. A census of the desert-breeding Damara Tern *Sterna balaenarum* in Namibia. Proceedings of the 8th Pan-African Ornithological Congress 95–398.

Simmons S and Braine S. 1994. Breeding, foraging, trapping and sexing of Damara Terns in the Skeleton Coast Park, Namibia. Ostrich 65:264–273.

Simmons RE, Cordes I and Braby RJ. 1998a. Latitudinal trends, population size, and habitat preferences of Damara Terns *Sterna balaenarum* on Nambia's desert coast. Ibis 140:439–445.

Simmons RE, Boix-Hinzen C, Barnes KN, Jarvis AM and Robertson A. 1998b. Important Bird Areas of Namibia. Pp 295–332 *in* The Important Bird Areas of southern Africa (Barnes KN, ed.). BirdLife South Africa, Johannesburg.

Simmons RE and Cordes I. 2000. Why is shorebird density so high in Walvis Bay? Delayed blooming and Benguela upwellings. Southern African Journal of Aquatic Sciences 25:229.

Simmons RE. 2005a. Damara Tern. Pp 464–465 *in* Roberts Birds of Southern Africa (Seventh Edition, Hockey PAR, Dean WRJ and Ryan PG, eds). John Voelcker Bird Book Fund, Black Eagle Publishing, Cape Town.

Simmons RE. 2005b.Declining coastal avifauna at a diamond mining site in Namibia: comparisons and causes. Ostrich 76:97–103.

Simmons RE**,** Sakko A, Paterson J and Nzuzi A. 2006. Birds and conservation significance of the Namib Desert's least known wetland: Baia dos Tigres, Angola. African Journal of Marine Science 28:713–717.

Simmons RE and Brown CJ. 2008. Birds to watch in Namibia: red, rare and endemic species. National Biodiversity Programme and Namibia Nature Foundation, Windhoek.

Simmons RE. 2010. First breeding records for Damara Terns and density of other shorebirds along Angola's Namib Desert coast. Ostrich 81:19–23.

Skutch AF. 1949. Do tropical birds rear as many young as they can nourish? Ibis 91:430–455.

Smith M and Heemstra PC. 1986. Smith's sea fishes. MacMillan, Johannesburg.

Slagsvold T. 1984. Clutch size variation in birds in relation to nest predation: on the cost of reproduction. Journal of Animal Ecology 53:945–953.

Southern WE. 1977. Colony selection and colony site tenacity in Ring-billed Gulls at a stable colony. Auk 94:469–478.

Southern LK and Southern WE. 1979. Philopatry in Ring-billed Gulls. Proceedings of the 1979 Conference of the Colonial Waterbird Group 3:27–32.

Southern LK and Southern WE. 1982. Effect of habitat decimation on Ring-billed Gull colony - and nest site tenacity. Auk 99:328–331.

Spendelow JA and Nichols JD. 1989. Annual survival rates of breeding Roseate Terns. Auk 106:367–374.

Spendelow JA 1991. Post-fledging survival and recruitment of known-origin Roseate Terns *Sterna dougallii* at Falkner Island, Connecticut. Colonial Waterbirds 14:108–115.

Spendelow JA, Nichols JD, Nisbet IC, Hays H, Cormons GD, Burger J, Safina C, Hines JE, and Gochfeld M. 1995. Estimating annual survival and movement rates of adults within a metapopulation of Roseate Terns. Ecology 76:2415–2428.

Spendelow JA, Nichols JD, Hines JE, Lebreton J-D and Pradel R. 2002. Modelling postfledging survival and age-specific breeding probabilities in species with delayed maturity: a case study of Roseate Terns at Flakner island, Connecticut *in* Statistical analysis of data from marked bird populations (Morgan BJT and Thomson DL, eds). Journal of Applied Statistics 29:385–405**.**

Summers RW and Cooper J. 1977. The population, ecology and conservation of the Black Oystercatcher *Haematopus moquini*. Ostrich 48:28–40.

Stearns SC and Crandall RE. 1981. Quantitative prediction of delayed maturity. Evolution 35:455–463.

Stearns SC. 1992. The evolution of life histories. Oxford University Press, New York.

Steiner UK and Gaston AJ. 2005. Reproductive consequences of natal dispersal in a highly philopatric seabird. Behavioral Ecology 16:634–639.

Stenhouse IJ and Robertson GJ. 2005. Philopatry, site tenacity, mate fidelity and adult survival in Sabine's Gulls. Condor 107:416–423.

Stenhouse IJ, Robertson GJ and Gilchrest HG. 2004. Recoveries and survival rate of Ivory Gulls banded in Nunavut, Canada, 1971–1999. Waterbirds 27:486–492.

Stienen EWM, Van Beers PWM, Brenninkmeijer A, Habraken, JMPM, Raaijmakers MHJE and van Tienen PGM. 2000. Reflections of a specialist: patterns in food provisioning and foraging conditions in Sandwich Terns *Sterna sandvicensis*. Ardea 88:33–49.

Tarr P. 2009. Namib-Skeleton Coast National Park: One of the largest parks in the world. Pp 4–7 *in* Conservation and the Environment in Namibia (van Schalkwyk R, ed.). Venture Publications, Windhoek.

Taylor IR. 1983. Effect of wind on the foraging behaviour of Common and Sandwich Terns. Ornis Scandinavia 14:90–96.

Tjørve KMC. 2007. Does chick development relate to breeding latitude in waders and gulls? Wader Study Group Bulletin 112: 12–23.

Tree T. 2000. Further on the Damara Terns at Cape Recife. Bee-eater 51(2):19.

Underhill LG and Whitelaw DA. 1977. An ornithological expedition to the Namib Coast. Western Cape Wader Group, Cape Town.

Underhill LG, Cooper J and Waltner M. 1980. The status of waders (Charadrii) and other birds in the coastal region of the southern and eastern Cape, summer 1978/89. Western Cape Wader Study Group, Cape Town.

Underhill LG, Crawford RJM, Wolfaardt AC, Whittington PA, Dyer BM, Leshoro TM, Ruthenberg M, Upfold L and Visagie J. 2006. Regionally coherent trends in colonies African Penguins *Spheniscus demersus* in the Western Cape, South Africa, 1987–2005. African Journal of Marine Science 28:697–704.

Underhill LG. submitted. Extensions to the Mayfield method for estimating nest success. Emu.

Urban EK, Fry CH and Keith S. 1986. The Birds of Africa. Volume 2. Academic Press, London.

van der Merwe JH (ed.). 1983. National atlas of South West Africa (Namibia). Cape Town, National Book Printers.

Veen J, Overdijk O and Koning H. 2003. Zilvermeeuwen en andere kolonievogels op Schiermonnikoog: onderzoek in het kader van het beheer 1997-2002. VEDA Consultancy, Wiesel.

Veen J, Peeters J and Mullié W. 2004. Manual for monitoring seabird colonies in West Africa. Wetlands International 2004 – internal report. Published by Wetlands International. www.wetlands.org Last accessed 9 August 2010.

Vincent AW. 1946. On the breeding habits of some African birds. Ibis 88:48–67.

Wallace DIM. 1973. Seabirds at Lagos and in the Gulf of Guinea. Ibis 115:559–212.

Watson JJ. 1995. Dune-breeding birds and human use of the Alexandria coastal dunefield: interactions and management implications. Masters Thesis, University of Port Elizabeth, South Africa.

Watson JJ, Kerley GIH and McLachlan A. 1997. Nesting habitat of birds breeding in a coastal dunefield, South Africa and management implications. Journal of Coastal Research 13:36–45.

Watson J. 1998. Battle for the Dunes: East coast Damara Terns on the Alexandria Coastal Dunefield. Africa - Birds and Birding 3(2):55–59.

Wedepohl PM, Lurjeharms JRE and Meeuwis JM. 2000. Surface drift in the south-east Atlantic Ocean. South African Journal of Marine Science 22:71–79.

Wendeln W. 1997. Body mass of female Common Terns *Sterna hirundo* during courtship: Relationships to male quality, egg mass, diet, laying date and age. Colonial Waterbirds 20:235–243.

White GC and Burnham KP. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46:120–139.

Whittington PA and Klages NTW. 2006. Tourism options for the Alexandria dunefield and beach. Limiting impacts on breeding and resident avifauna. Report prepared for South African National Parks. IECM Report C140. Integrated Environmental and Coastal Management, Nelson Mandela Metropolitan University, Port Elizabeth.

Wilbur SR. 1974. The literature of the California Least Tern. U.S. Fish Wildlife Report 175:1–18.

Williams AJ and Myer EJ. 1986. Damara Terns: nonbreeding population and post-fledging feeding in the Lüderitz area of SWA/Namibia. Lanioturdus 22:3–4.

Williams AJ, Ward VL and Underhill LG. 2004. Waders respond quickly and positively to the banning from beaches in South Africa. Wader Study Group Bulletin 104:79–81.

Williams AJ. in prep. Sand-swamping, predation, avoidance, and human disturbance effects on endangered Damara Terns *Sterna balaenarum* breeding at Struisbay, South Africa.

Williams TD and Croxall JP. 1990. Is chick fledging weight a good index of food availability in seabird populations? Oikos 59:414–416.

Whittier JB and Leslie Jr DM. 2005. Efficacy of using radio transmitters to monitor Least Tern chicks. Wilson Bulletin 117:85–91.

Wooller RD, Bradley JS and Croxall JP. 1992. Long-term population studies of seabirds. Trends in Evolutionary Ecology 7:111–114.

World Bank. 2009. Total population of Namibia. http://data.worldbank.org Last accessed 1 November 2010.

Zar JH. 1999. Biostatistical Analysis. 4th Edition. Prentice-Hall, Upper Saddle River, New Jersey.

Zavalaga CB, Plenge MA and Bertolero A. 2008. The breeding biology of the Peruvian Tern *Sterna lorata* in Peru. Waterbirds 31:550–560.

Zuria I and Mellink E. 2002. Natural and human impacts on two Least Tern colonies in northwestern Mexico. Southwestern Naturalist 47:617–623.

Appendix 1

Appendix 1: New and updated information on the aspects of breeding biology of the Damara Tern *Sterna balaenarum* (b) compared with information provided by Simmons RE (2005a) (a).

	Sample size		**Mean**		**Range**	
	a	b	a	b	a	b
Clutch size	577	2528	1 (99%)	1 (99.998%)	n/a	n/a
Egg length (mm)	263	586	32.2	33.09	29.6–36.2	30.55–37.12
Egg breadth (mm)	263	586	23.8	23.84	22.1–25.3	21.00–25.8
Volume (ml)	7	586	8.57	8.96	7.26–10.77	6.71–10.81
Egg mass (fresh) (g)	7	12	9.3	10.17	–	9.3–11.5
Egg mass (pipping) (g)	7	68	7.5	7.92	–	6.5–9.7
Incubation period (days)	8	106	18-22	23	17.5–30	19–31
Fledging period (days)	1	10	20	23	–	21–24
Overall breeding success (Namibia)	–	–	0.53	0.38	–	
Feeding rate (fish/hr/chick)	8	36	0.5	1.44	0.4–1.25	0-4.5
Mean chick growth rate (mass, g/day)	–	282	–	0.99	–	–
Chick at hatching						
Mass (g)	18	118	6.5	7.05	4.8–7.6	4.8–9
Bill (mm)	2	26	7.7	7.58	–	6.60–8.68
Wing length (mm)	–	37	–	11.89	–	6.97–17.96
Head length (mm)	–	32	–	24.75	–	22.62–27.60
Foot length (mm)	–	30	–	20.28	–	18.50–22.39
Chick at fledging						
Mass (g)	1	10	40	43.5	–	40–47
Bill (mm)	1	4	17.3	17.9	–	15.80–18.8
Wing length (mm)	1	5	88	100.82	–	101–106
Head length (mm)	–	3	–	45.01	–	44.34–46.14
Foot Length (mm)	–	3	–	28.78	–	28.61–28.97
Adult						
Mass (g)	46	397	51.8	50.99	46.5–62.5	42-63
Bill (mm)	46	350	29.7	30.1	27.7–32.8	25.5–61
Wing length (mm)	45	401	166.05	172.21	155–176	152.59–175
Head length (mm)	–	297	–	62.27	–	48–72
Foot length (mm)	–	10	–	28.25	–	26.78–30.52
Tarsus (mm)	45	237	12.8	16.6	11.6–14.7	11.10–19.50
Immature survival	–	214	–	0.59	–	–
Age at first breeding	–	214	–	3,4	–	–
Adult survival	–	214	–	0.88	–	–
Breeding dispersal	–	214	–	0.06	–	–

Annexes

Annex 1: Excerpt of an article found on the Southern African Bird Atlas 2 Project Website (http://sabap2.adu.org.za/news_list_all.php). This article was reproduced and translated from the original Afrikaans letter (and photo) sent to the newspaper "Republikein" (19 November 2010) by Mr. T. de Wit, a tourist visiting Angola.

Terns trapped and kept alive, sold fresh for food in Angola

Justine Braby is an ADU PhD student, based in Swakopmund. One of the Namibian newspapers, **Die Republikein**, has a column entitled "Dinge wat krap" (things that alarm/irritate). Justine found the following story in this column on 19 November 2010, together with this picture, taken by a resident of the northern Namibian town of Tsumeb.

The citizen reports: "This photo was taken a week ago in Tomwa, Angola, during a visit. These birds are Damara Terns *Sterna balaenarum* which are caught and sold by the local people. They use a baited hook on a fishline. The wings are broken and the birds are buried in the sand so that just the head sticks out. They are kept alive and sold later to eat. We saw other places along the coast where larger birds were caught for the same purpose. Absolutely tragic. I plan to report this to the authorities on my next visit to

Angola."

Although the birds in the picture were identified as Damara Terns most of them look more likely to be Common Terns. But we are fairly certain that there are some Damara Terns among them. Regardless of what species is involved this represents a serious conservation problem. A similar issue arose in Ghana about 20 years ago, and the problem there was tackled by establishing "wildlife clubs" at many villages along the coast. The Common Terns on passage southward along the Angolan coastline at this time of the year would be mainly from the Baltic Sea region, with the birds having bred in countries such as Sweden, Norway, Finland, Poland, Estonia, Lithuania, Latvia and Denmark. Damara Terns, in contrast, breed mainly along the desert coastline of Namibia. They don't breed along the shoreline, but several kilometres (up to 10 km) inland, so they can reduce the risk of predation from jackals, which patrol the coastline for dead and sick seals, and anything else they can scavenge. They breed from November to February, and the migrate north to spend the nonbreeding season in West Africa, in countries such as Ghana and Nigeria. So Damara Terns passing along the Angolan coastline now would be pretty close to their breeding destinations in Namibia.

The editor, Chris Jacobie, of Die Republikein gave permission for this picture, and the accompanying story, to be reproduced here. He commented: "A collusion of the article and the knowledgeable must help in some way”.

Annex 2: The following excerpt is reproduced from the methodology written by le Roux (2006) for the study of growth in Swift Terns *Sterna bergii*:

"Statistical analysis for growth curves for Swift Terns

The growth patterns of most measurements did not conform to the standard growth curves, such as logistic or Gompertz (Reiss 1989). A new descriptive statistical approach was therefore devised. For all chicks that were captured more than once, growth rates were calculated between each pair of captures for mass and for each structure: wing length, head length, culmen length, tarsus length and foot length. The average of the pair of measurements was also calculated. For example if successive masses at times t and u were m_t and m_u, the growth rate over this time period is g = (change in size)/(time period) = $(m_t – m_u)/(t – u)$ and the average of the pair of measurements is $a = (m_t + m_u)/2$. All the pairs of values (a, g) were plotted. This was done for mass and for each length measurement. Identical "growth-rate vs size" plots were produced by Schoener and Schoener (1978) in their analysis of growth rates of lizards. These growth-rate vs size plot are referred to as "growth rate plots".

The initial focus was on growth in mass. For a set of target masses at small increments between hatching mass and fledging mass, the average growth rate at each of these masses was estimated. This was achieved by using weighted regression. For the target mass at which growth rate needed to be estimated, weights for all the pairs of observations were calculated (a, g) in such that values close to the target mass had large weights and values farther away had increasingly smaller weights. If the target mass was m^*, then the weight w attached to observation (a, g) was $w=\exp(–((a–m^*)/\sigma)^2)$ where σ was chosen to be 8.0. This is about 2.4% of the adult mass (see below). This results in weights attached to observations 8 g distant from the target mass being substantial (weight 0.37), at 12 g distant the weight (0.105) is small, and at 16 g distant the weight (0.018) is tiny. Observations more than 16 g distant from the target mass thus have negligible weights to the regression calculations. The weighted linear regression was fitted to predict growth rate from mass using these weights, and this regression line, fitted by GenStat8 (Payne *et al.* 2005) was used to predict the growth rate g^* at the target mass. Using this weighted approach, this estimated growth rate then depends on observed growth rates in the neighbourhood of the target mass.

By varying σ, the length of the influential neighbourhood can be modified. The smaller the value of σ, the shorter the neighbourhood, the fewer observations are effectively included, and the estimated growth rate at the target masses are based on small samples and tend to be unstable. The larger the value of σ, the wider the neighbourhood and the more stable the estimates; however, the inclusion of growth rates distant from the target mass can result in biases. There is thus a trade-off between values of σ which are large enough to prevent instability of the estimates and values which are small enough that the estimate refers to a small neighbourhood of the target mass. A similar compromise has to be made in various statistical smoothing methods (Silverman 1986), where the amount of smoothing depends on the size of the smoothing window (frequently referred to as "bandwidth"); too small a window results in little smoothing, too large a window results in over-smoothing, with important aspects of the data being obscured. There are automatic methods to choose the width of the smoothing window, but the best approach remains visual inspection of the results (Silverman 1986). The visual inspection approach was used to choose $\sigma = 8$; however, the results do not depend critically on the choice of a particular value for σ, the experimentation showed that if a chosen value was twice as large or half as small, the results would have been nearly identical.

An approximate standard deviation of mass at each target mass was estimated. The same weights used for the regression were used to estimate a weighted standard deviation s_{m^*}; the formula $s_{m^*}=(1/\sum w)((w(g–g^*)^2)$ was used.

An approximate coefficient of variation for each target mass was calculated as CV*= 100 × (s_{m*}/m^*). This coefficient of variation provides a measure of the variability of the growth rate for each target mass.

The estimated growth rates at each target mass were plotted, and the points were linked using an interpolated line. Likewise, approximate lower and upper confidence limits for the growth rates were plotted. A normal distribution was assumed, so that the lower and upper confidence limits were $g^*–1.96\ s_{m*}$ and $g^* + 1.96\ s_{m*}$ respectively. Using hatchling mass as the starting value on day 0, the growth rate curve was integrated to produce a plot of mass against time. This provides a non-parametric growth curve which describes the pattern of growth as determined by the data rather than forcing the data into a pattern as a consequence of the parametric model chosen by the analyst.

For each successive pair of measurements on a chick, a comparison was made between the observed growth rate and the expected growth rate in the interval between the two measurements. The expected growth rate was computed at the average of the two measurements, and its approximate standard deviation calculated as described above. The standardized growth rate was then compute using the conventional approach to standardization – dividing the difference between the observed and expected growth rate by the standard deviation. In symbols, if the observed growth rate is g, the predicted growth rate is g^* and the estimated standard deviation at this growth rate is s^*, then the standardized growth rate z is defined to be $z = (g–g^*)/s^*$. For large samples, the overall mean of all z-values is asymptotically zero; negative values indicate below average growth rates and positive values indicate above average growth rates. The z-values can be interpreted as an index of the extent to which growth in the interval is above or below expected; through the mechanism of dividing by the standard deviation, the index is independent of the stage of growth. In other words, the z-values, which are dimensionless, represent a common currency to measure departures from "average" growth, which are independent of whether growth is measured early when the absolute growth rates (g/day or mm/day) tend to be small, at the maximum growth spurt, when growth rates tend to be large, or late in growth, when growth rates tend to be decreasing.

If the analyst is prepared to make the assumption of normality (which to a first approximation is probably reasonable), the magnitudes of z-scores can be expected to be in keeping with the standard normal distribution; for example, approximately 95% of the z-scores can be anticipated to lie between the values –1.96 and +1.96; less than 0.5% of the values can be anticipated to be smaller than –2.58 or larger than +2.58. These large values should be screened to consider the possibility that one or other of the measurements were erroneous...

Although the description of the statistical method above is in terms of mass, it also applies to the length measurements of structures such as bill length and wing length."

Plates

(a)

(b)

(c)

(d)

Plate 1: Photographs of nests illustrating the importance of substrate in egg camouflage at each colony in southern Namibia, (a) Hottentots Bay, (b) Grosse Bucht, (c) Elizabeth Bay, and (d) Marmora Pan.

Rod Braby

(a)

Rod Braby

(b)

Plate 2: Aerial photographs showing off-road vehicle tracks (a) between the main road and the beach, and (b) east of the main road. Both pictures were taken in the Dorob National Park, between the Ugab River and Swakopmund, Namibia.

Plate 3: Photographs of conservation measures put in place at Horses Graves and Caution Reef in central Namibia.

(a)

(b)

(c)

Plate 4: Photograph illustrating the level of discharge of sediment into the sea as a result of diamond mining at Elizabeth Bay in southern Namibia, (a) full, (b) moderate, and (c) trickle.

(a)

(b)

(c)

(d)

Plate 5: Photographs illustrating different breeding habitats of Damara Terns in southern Namibia; (a) Hottentots Bay, (b) Grosse Bucht, (c) Elizabeth Bay, and (d) Marmora Pan.

Hatchling

c. One week

c. Two weeks

c. Three–four weeks

Plate 6: Damara Tern chicks in different stages of development.

(a)

Unknown

(b)

Kerry Steinberner

(c)

Plate 7: The most common predators of Damara Tern eggs and chicks, the (a)Black-backed Jackal *Canis mesomelas*, (b) Pied Crow *Corvus albus*, and (c)Kelp Gull *Larus dominicanus*.

17.3.

THE DAMARA TERN STATUS UPDATE

The Damara Tern: What we know and what we don't

Prepared for the Namibian Coast Conservation and Management Project (NACOMA) for the publication and release of information for public interest

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Date: 1st April 2010

Table of Contents:

1. What does the Damara Tern look like?

The Damara Tern belongs to the 'little tern' complex of which seven species occur globally, each adapted to the specific region it belongs to. The average mass of the Damara Tern is 51 g and it has an average wing length of only 17.3 cm. It is the smallest breeding tern in Africa and among

the smallest globally. The Damara Tern changes appearance in the breeding season becoming more attractive in order to secure a mate. In full breeding plumage the Damara Tern has a black cap and is gray on its back, wings and tail, with a white breast and belly. Its bill is slightly curved, black with a section of orange/yellow at the base. In non-breeding plumage, the Damara Tern loses its predominant black cap which becomes mottled grey and blackish brown with a white forehead. It is a fast-flying tern with a shallowly forked tail.

2. Where does the Damara Tern occur?

Damara Terns are mostly migratory, with a very small population (<100) resident in southern Africa all year round. Around September and October Damara Terns start arriving at their breeding localities in Angola, Namibia and South Africa. The vast majority (98%) breed in Namibia, along a coastline where the harsh Namib Desert meets the icy Benguela Current of the Atlantic Ocean. Here the productivity is highest because of the Benguela Upwelling System. Once the breeding season is over

the adults and the small percentage of surviving flighted chicks make the 4 000 – 5 000 km journey northwards ending up along the west-African coastline to countries like Cameroon, Nigeria, Benin and Ghana. Recent captures and sightings of ringed individuals have added valuable information to our growing knowledge of the movements of this little seabird. A South African individual that was ringed as a chick in December 1999 was found in Benin in October 2000, 10 months and 4 948 km later. Five ringed individuals were sighted during a trip to Lagos, Nigeria in August 2008. It is suspected that all five were Namibian born and bred, but one individual, because of its unique color ring combination, could be identified as a breeding adult that was captured over subsequent years (2003, 2007 and 2008) within 10 m of the same nest site at the breeding site called “Caution Reef” near Swakopmund, Namibia. This bird was captured on its nest in November 2008, less than two months after its sighting in Lagos, Nigeria (a direct journey of 3 400 km). Other migration records include a Damara Tern seen in Gabon in 2005 that was ringed as a chick at Caution Reef in 2001, and a Damara Tern that was captured and released in Benin in 2004 that was ringed as a chick at Caution Reef in 2001.

3. Feeding and diet

Damara Terns predominantly feed by plunge-diving for food. Once they locate a prey item (usually a small fish), they hover and dive to retrieve it. Damara Terns feed in sheltered bays, lagoons and estuaries, but have also been seen feeding on high-energy coasts. They feed in the shallows and within and beyond the surf zone. The Damara Tern's diet consists mainly of small fish and crustaceans. Food items collected from adults provisioning their chicks, and chick regurgitations include Needle fish (*Tylosurus* sp), mullet (*Mugil* spp), tiny squid (Cephalapoda sp), and anchovy (*Engraulies capensis)* as well as larval blennies (Blennidae).

4. Breeding Ecology

Damara Terns arrive around September and October at their respective breeding colonies. There is some movement of individual Damara Terns between colonies, however many Damara Terns return to the same breeding locality where they were born. Once arrived, individual Damara Terns display courtship behaviour and form pair-bonds. During the pair-bonding process, the male Damara Tern will present "gifts" (prey items) to the female. Once the pair-bond has been made, the pair is monogamous throughout the season, even if their first breeding

attempt is a failure (for instance if their egg or chick is predated and they have to make a second breeding attempt), they will stay together for other breeding attempts made during that season. The pair will copulate and then locate a nest site and make a “nest” together. This process takes only a few days. The female will then lay one egg. The nest consists of a scrape in the ground. Sometimes the nest is bare, sometimes there isn’t even a scrape, i.e. the female just lays the egg on the ground, and sometimes the nest is decorated with shells or small pebbles. In many cases the nest is within a feature, such as a tyre track or near a rock (through natural selection either a black or a white rock). This is thought to make locating the nest site from the air easier. The breeding habitat of Damara Terns varies from slacks in between dunes, gravel plains in between dunes, sandy plains, saltpans, extinct lagoons, stony plains and combinations of these. Distances of breeding areas from the sea vary from 100 m to as far as 11 km inland; however the average distance of nests from the sea in Namibian breeding colonies is 1 km. The distance between nests varies from as little as 30 m to 3 km within one colony, and in some instances single nests may occur with no neighbours for up to 20 km or more. The minimum number of nests within one breeding locality is one and the maximum number of nests within one breeding locality found so far is 187. However, the average number of pairs for all colonies is less than 30. The densest breeding colony is found between Swakopmund and Walvis Bay, the colony (collectively known as Caution Reef) is divided into two areas, namely ‘Horses Graves’ (inter-dune area) and ‘Caution Reef’ (coastal area), with inter-nest distances averaging at 50m. Once the female has laid her egg, the pair shares egg incubation duties over a period of 21 – 28 days, when the chick hatches out. During this incubation period there is a high risk of predation of the egg. If the chick successfully hatches, it is brooded for a minimum of two days. Depending

on the level of disturbance, the chick may move away from the nest just hours after hatching. However, most chicks, if undisturbed, will start moving from the nest at around 2 – 3 days. The brooding responsibility lies with both parents; while one parent is brooding, the other will take on the feeding responsibilities. As the chick gets older both adults provision the chick and the chick spends increasing amounts of time on its own. However, the majority of the day the chick is accompanied by at least one parent. The chick grows fast, with a hatching mass of 6 -7 g and a fledging mass, 23 days later, of 50 g. Once the chick is fully fledged, it will move to the beach where the food source is closer and parents can provision it more rapidly. Here the young fledgling also learns to feed for itself. The chick is dependant on its parents for at least two and a half months after fledging. If a pair loses its egg or chick, it will attempt to breed again, provided the loss did not occur too late in the breeding season. Chicks that fledge early in the breeding season have a longer time to prepare for the migration north to the west coast of Africa and are therefore likely to have a better chance of survival to adulthood.

5. Causes of breeding failures and predators

The most common cause of breeding failures is due to the predation of eggs and chicks. The most common predator of Damara Tern eggs and chicks is the Black-backed Jackal. Other predators include Pied Crows, Kelp Gulls, and Rock Kestrels. Un-common predators include Greater Kestrels, Ospreys, Booted Eagles, Brown Hyenas, African Wild Cats, Namaqua Chameleons, and possibly even gerbils and tenebrionid beetles. Damara Terns have adapted to minimize the risk of predation of their eggs and chicks in various ways:

1. The female Damara Tern predominantly lays one egg rather than two (which is the minimum clutch-size of all other terns); this may be an adaptive trait to accommodate for a high risk of predation- it is less expensive for the female to lose one egg to predation than two.
2. Both the egg and the chick are incredibly cryptic and blend in well with the surrounding environment.
3. Damara Terns prefer to nest on slightly higher ground to have better visibility of approaching terrestrial predators.
4. Damara Terns breed further inland than all the other small terns in order to avoid predators such as the Kelp Gull and the Black-backed Jackal which scavenge along the shoreline.

5. When a predator approaches a breeding area the Damara Terns will form groups and mob and chirp at the predator in order to distract it and deter it from the area.
Other breeding failures can be attributed to humans, sand-swamping of eggs, flooding of the breeding areas due to heavy rains or spring tides, exposure of chicks to extreme heat, cold or wind, and abandonment of nests for various reasons. Human induced failures include direct trampling by horses, off-road vehicles, footprints and dogs.

6. Breeding distribution: Which colonies are important?

An attempt is being made to locate and estimate breeding populations of all breeding colonies in Angola, Namibia, and South Africa. This investigation will estimate the entire breeding population based on all the colonies and attempt to identify which colonies are the most important. It is without doubt that the largest and most important breeding colonies occur on the coastline of Namibia. Less than 100 pairs occur in South Africa, with a similar or less pairs occurring in Angola. It is unknown exactly how many pairs breed in Namibia, but it is unlikely to be more than 2 500 pairs. Breeding colonies in the Sperrgebiet south of Lüderitz are generally small, with the largest colony at Marmora Pan, 250 km south of Lüderitz (maximum of 55 pairs). Two colonies exist north of Lüderitz which are significant in terms of breeding numbers, namely Hottentot Bay, and Meob Bay. The extinct lagoon and saltpan south of Hottentot Bay has been found to hold the largest number of breeding Damara Terns. However, this breeding area is below sea level and was once under water, and increased spring tides and rains have resulted in an increased occurrence of flooding. If flooding in this area becomes so frequent that Damara Terns can no longer breed, there will be

a displacement of up to 300 pairs. Little is known of the breeding population at Meob Bay, but is unlikely to be as large as at Hottentot Bay. Black-backed Jackals are common in this area and may restrict the success of breeding attempts. However, both these areas are protected from human disturbance by virtue of their isolation. This said, Meob Bay has in the past become more popular with off-road tour operators which may create increasing levels of disturbance to breeding terns. The breeding population between Swakopmund and Walvis Bay has been the most important in terms of conservation and breeding density. This breeding area holds a minimum of 160 breeding pairs, most of which show fidelity to this area. This breeding area is managed, protected and monitored every breeding season. The breeding populations north of Swakopmund in the National West Coast Tourist Recreation Area (NWCTRA) have been heavily disturbed by off-road driving and their breeding success is negligible, especially breeding areas west of the main coastal road which are continuously driven over by vehicles accessing the beach. Durissa Bay, 15 km south of the Skeleton Coast Park border, holds a significant breeding population, but the breeding success here is affected by a high density of predators, including Black-backed Jackals, Pied Crows and Brown Hyenas. There were sizable breeding populations within the Skeleton Coast Park, but these colonies have not been monitored since the early 1990s. A northward movement of seal populations into the Skeleton Coast Park, especially near previous breeding colonies, may have increased scavenger and predator abundance and thus may have had a negative impact on breeding success and number of breeding Damara Terns in the breeding areas of the Skeleton Coast Park. Short-term monitoring of the previous breeding areas here should be conducted to investigate whether these breeding populations still occur or have since been pushed to the brink of extinction.

7. Anthropogenic Threats

7.1. Housing and industrial development

Human development resulting in breeding habitat loss is the biggest threat facing the Damara Tern. Various colonies have become extinct due to development on areas where they previously nested. The breeding colony of at least 32 pairs that bred at Dolphin Beach is now extinct due to the development of the ironically-named Eco-village and Aphrodites Beach. These developments occurred during the breeding season of 2005 and resulted in direct losses of eggs and chicks. No terns breed in this area anymore. The largest and supposedly most protected colony, at Caution Reef, between Swakopmund and Walvis Bay is under threat because of proposed developments. If development occurs in this dense breeding area, the number of young additions to the global population will decrease substantially.

7.2. Off-road driving and other recreational disturbance

Off-road driving has resulted in direct nest losses in Damara Terns and has added to a general low breeding success in most colonies affected by such disturbance. All 11 pairs that bred at Struis Bay, South Africa, raised a chick to fledging before January the season directly following the ORV ban on beaches in South Africa (2001), a first in six years of monitoring, indicating the direct positive response to the ban of ORV on beaches. However, since the ORV ban in South Africa, the number of ORV drivers over the holiday season (which unfortunately coincides with the Damara Tern breeding season) on the Namibian coastline increased exponentially. The breeding areas that are most affected, or have been in the past, stretch from Sandwich Harbour (arguably even as far south as Meob Bay) north to the border of the Skeleton Coast Park. Even in areas south of this, within the Sperrgebiet and the recreational areas around Lüderitz, are vulnerable to off-road vehicles. The management approach taken to avoid, or at least minimize the disturbance caused by off-road vehicles, have been either informative, in the form of signs, like near Mile 72 in the NWCTRA, or Grossebucht near Lüderitz, or restrictive, in the form of fences around breeding colonies, like at Caution Reef, between Swakopmund and Walvis Bay. Other recreational disturbance include people walking either on their own, with their pets or riding horses through breeding areas, there-by trampling nests and chicks. In some instances, even picnicking people may have a negative impact. One example of this is of a group of unknown people that made a fire within the prohibited Damara Tern breeding area at Caution Reef during New Year's night, within metres of a chick that was in the process of hatching. The Damara Tern parent could not brood the chick due to this disturbance and the chick died of exposure during the night.

7.3. The impacts of mining

Coastal mining potentially has direct negative impacts on the reproductive success of the Damara Tern. Most of the southern coastline of Namibia is a diamond area and as such is not open to the public. Tern breeding areas within the restricted area where no actual mining is taking place are protected largely by virtue of their isolation. However, if viable diamond deposits were to be found within these areas, these breeding areas would be severely threatened. There are various breeding colonies which may, or have been disturbed by diamond mining. At Elizabeth Bay the foraging success of the Damara Tern breeding colony is affected by the substantial release of fine sediment into the bay which decreases water clarity. At Marmora Pan a large-scale diamond extraction project was underway within 10 km of the breeding area, however, this has since been removed and rehabilitated. Within the diamond mining areas of the northern Cape in South Africa, especially at Alexander Bay, large-scale mining resulted in breeding habitat destruction. Within the Skeleton Coast the breeding colonies could be affected if prospecting yields payable mineral deposits and results in mining. However, if the entire coastline receives National Park status, the Damara Tern breeding areas will be protected by the zoning of areas of biodiversity importance into “no go” areas.

8. A Case Study in Conservation: Caution Reef

The breeding area known as Caution Reef has been monitored since the early 1990s. By 1998 the decrease in breeding numbers and success could mainly be attributed to off-road vehicles directly disturbing the breeding ground of the Damara Terns. In addition uncontrolled off-road driving was creating other disturbance to the natural environment. By 2001 it was realized that if no management action was taken, this large breeding colony would become extinct and thus the existence of the species as a whole may then hang by a thread. So it was decided to create zones just east of the beach and within the dune belt for various uses, including eco-tourism and quad-biking tours among others. The Damara Tern breeding areas were closed off from the public by erecting fences around the perimeter and placing signs around this perimeter informing the public about the vulnerability of the breeding terns. This area covered less than 10% of the entire dune belt area. Entry points and corridors for quad-bikes and other off-road vehicles were placed at strategic points along the dune belt, and the majority of the dune belt was still open for the public to enjoy. In addition, beach-driving was still allowed so that the public can enjoy recreational activities on the beach. The entry points and open-access areas were discussed and were open to public opinion and input before this zoning was completed. Everyone wanting to drive within this dune belt had to obtain a free permit at various offices available to them. This management plan resulted in the protection of the Damara Tern breeding areas and results of this could be seen the very next breeding season, with breeding numbers and success more than doubling after the barrier was erected. Two papers were published on the success of these conservation measures. However, although meetings regarding the zoning of the dune belt that were held included public opinion, and 90% of the dune belt is still open to the public for off-road recreational use, antagonism towards

fencing and prohibiting entry into the breeding areas still exist, surprisingly, and every season since 2001 there have been sporadic occurrences of people collapsing fences and rushing through areas on quad-bikes, motocross bikes and off-road vehicles, with nests containing eggs or chicks being crushed by this or tracks coming within centimeters of active nests. The Damara Tern is integral to the near-shore marine ecosystem, although its role within it is not yet fully understood. As such the importance of preserving this species is a prime example of a wildlife conservation objective to promote the co-existence of all organisms so that the biological diversity in natural systems can be maintained. Compromises have been made for the recreational use of off-road vehicles within the dune belt at the cost of various endemic creatures; the protection of these species should be understood by the public and not frowned upon as a restriction to their own needs for fun and play in the dunes. The understanding that we share the dune and beach ecosystem with other living creatures should be clear and obvious to us, the people who make use of these ecosystems. It has been proven that, if responsibly done, ORV recreational users can still enjoy these areas without destroying them. However, a few who continue to disrespect our natural heritage by blatantly destroying it, such as collapsing fences around protected areas and driving straight through vulnerable areas and killing the natural life within them, will cause the loss of our natural heritage for all of us, our generation, and the next to come.

9. Why conserve species like the Damara Tern?

To answer this question I have added on an essay written by Martin Sharmann, who wrote about a change in our consideration of what we find intrinsic and important. Extinction is a fact of life. Species have been evolving and dying out ever since the origin of life. One only has to look at the fossil record to appreciate this fact. However, species are now becoming extinct at an alarming rate, almost entirely as a result of human activities. Through poverty, greed, thoughtlessness and the sheer vastness of the needs of the human population, humans are bringing about a mass extinction comparable with any of the five great disasters that have destroyed the vast majority of life on Earth in the past 530 million years. The United Nations Convention on Biological Diversity, of which Namibia is a signatory, states in its preamble: “conscious of the intrinsic value of biological diversity…” and continues: “conscious also of the importance of biological diversity for evolution and for maintaining life sustaining systems of the biosphere…”. In signing up to this document, almost every State on earth has agreed that biodiversity has value that has nothing to do with human perceptions. From this viewpoint, humans are relevant only as the agents of the premature extinction of species. The Convention, in its first paragraph, also comments on the importance of conserving species because they enrich our lives, and help to preserve human economics, societies and cultures. But this suggests only the conservation of species specifically to accommodate our own needs. Just because we have the capacity to arrogate for ourselves the resources of the planet, does this give us the right? Do humans then also have an axiomatic right to extinguish species? Should we include other species in our consideration of what constitutes principal behaviour? Unfortunately nowhere does the Convention on Biological Diversity use the words 'moral' or 'ethical' or hint that humans have a responsibility to respect other species. Part of what should make anyone want to conserve biodiversity is what he/she believes to be morally right and wrong. Regrettably some of the shapers of society's perceptions have labeled such behaviour as "bunny-hugger" behaviour and it is often frowned upon, instead of perceived as basic human decency and morality. An additional reason for cherishing biodiversity, and a more globally accepted one, concerns itself with stewardship and inheritance. What human-beings would not want their children or grandchildren to live in a world that still houses other life-forms? Humans are the engineers of climate change, habitat fragmentation, pollution, over-harvesting, over-exploitation and all other woes we inflict on our living planet. The natural sciences can help us understand genetic loss, or the functioning of ecosystems, or whether fragmented populations can survive. This work is necessary, but not sufficient. With few or no exceptions, a plan to conserve biodiversity will only work if we deal with our own mindsets. We must understand how we and our neighbours and people with entirely different cultures and world views perceive and value biodiversity. If our progeny are to enjoy some of the biodiversity that surrounds us today, we must learn how to reframe our economic and social needs and goals so that we no longer damage our own biological environment. Economic growth is a fundamental characteristic of industrialized countries. But in a closed system you can not sustain economic growth for ever. The last few decades have shown that economic development and the conservation of nature almost never go hand in hand. The rewards for preserving and cherishing nature are often long-delayed and all too typically accrue to the wrong people. The problem of the loss of biodiversity is a problem of human behaviour and aspirations. What will it take before men and women of all ages, in all cultures of the world, want to conserve nature and protect biodiversity – or at least not destroy it? If we cannot understand the simple intrinsic value of all creatures, whether great, like the African Elephant and Blue Whale, or small, like the Damara Tern, we will go on losing biodiversity. Our world will become a less interesting place, our children will not thank us, and we will have the rest of our short lives to grieve the ineluctable passing of much of what makes life beautiful.

10. An important consideration regarding off-road recreational driving in coastal Namibia

Namibia is one of the only countries in the world in which beach-driving is still allowed. In South Africa beach-driving has been banned since 2001 and it is common knowledge that beaches, beach dunes, coastal marshes are extremely fragile and should be avoided completely. Aerial photographs of the coastline of Namibia, especially north of Swakopmund all the way to the Ugab River, reflect a landscape that is severely scarred by people driving recklessly off tracks and venturing into areas where no other vehicles have driven. Driving off established tracks destroys ancient life-forms every metre of the way. Every time someone leaves an established track, a new scar is created on the landscape, and the chances are good that vehicles after this will follow these tracks thinking it is an established route. On the coast of Namibia, the conservation authorities have set up various rules and regulations in order for off-road drivers to enjoy the coastline without destroying it. At towns and settlements beach-driving is prohibited. Corridors were demarcated which could be used for quad-bikes and other vehicles to access the dunes between Walvis Bay and Swakopmund. From the Kuiseb Delta to the Ugab River, people may go anywhere on proclaimed roads, on the beach or along existing, well-used tracks. It seems that the conservation authorities have made major compromises for the enjoyment of off-road vehicle users. Unfortunately, even though people are allowed to essentially drive almost anywhere within reason, many off-road drivers disrespect the rules and still drive off-road, off the tracks, and destroy each metre of land in front of them at the expense of both the natural environment, which will not look the same again for hundreds of years – even if just one track has sliced through it- and the off-road drivers who actually respect the rules and regulations and understand why they are in place. Deserts and beaches are the most fragile ecosystems regarding off-road driving, both of which have been seriously carved up by ORVs along the coastline of Namibia. Driving north of Swakopmund, one can identify a track almost every 10 metres traversing west of the main road towards the beach. Although

vehicles need to have access to the beach, it is not necessary to have this access every 10 – 50 metres. Almost every metre of desert coastline between the town Swakopmund and the border of the Skeleton Coast Park at Ugab has tracks on it. There has been a slow change in people understanding the fragility of our coastline, and the longevity of ORV tracks

on desert landscapes, especially in extremely sensitive areas like lichen fields. In our day and age the behaviour of traversing through a pristine piece of desert landscape should induce a cringing feeling in the pit of one's stomach. Instead many people, aware of the consequences of their actions or not, continue to drive around carelessly and without regard, killing life-forms in their wake and leaving behind an ugly and irreversible sight. If these off-road drivers cannot understand the importance of both protecting other life-forms and the essential beauty of the pristine desert, whether for moral, ecological and even economical obligations, they should at least consider that their actions will induce an eventual off-road ban along the coastline of Namibia, much like what has been done in other countries like South Africa. And an induced ban followed as a result of loss of control of disrespectful off-road drivers who disregard the intrinsic value of protecting the natural heritage that only a few countries in the world can still boast, will stop everyone from enjoying the beaches we once did, both the law-breakers, and the off-road drivers who appreciated the rules and regulations.

11. References

Braby S. 2006-2009. Monitoring reports of the breeding success of the Damara Tern at Caution Reef and Horses Graves. Unpublished reports.

Braby, R.J., Braby, S.J. & Simmons, R.E. 1992. 5000 Damara terns in the northern Namib desert. A reassessment of world population numbers. *Ostrich* 63: 133-135

Braby, R.J., Shapira, A. & Simmons, R.E. 2001. Successful conservation measures and new breeding records for Damara Terns *Sterna balaenarum* in Namibia. *Marine Ornithology* 28:81-84

Braby J., Braby R.J., Braby N. and Simmons R.E. 2009. Protecting Damara Terns *Sterna balaenarum* from recreational disturbance in the Namib Desert increases breeding density and overall success. Ostrich. 80(2): 71 – 75.

Braby J. and Kesmen D.S. 2009. 40-year comparison of seabirds and migrant Damara Terns *Sterna balaenarum* at beaches around Lagos, Nigeria. Submitted.

Braby J. 2009. Namibia's desert-breeding seabird. *Conservation, and the Environment in Namibia*. 44-45.

Braby J. 2008. Damara Tern piece in: Many happy re-terns. *Africa-Birds and Birding*. 13(6): 54

Braby J. 2010. The Biology and Conservation of the Damara Tern *Sterna balaenarum*. PhD Thesis in prep, Animal Demography Unit, University of Cape Town.

Brown, R.G.B. 1979. Seabirds of the Senegal upwelling and adjacent waters. *Ibis*. 121: 283-121

Bourdillion, B.H. 1944. Terns on Lagos Beach, Nigeria. *Ibis*. 405-407.

Clinning, C.F. 1978. The biology and conservation of the Damara Tern in South West Africa. *Madoqua* 11:31-39

Crawford, R. & Simmons, RE. 1997. Damara Tern *Sterna baleanarum*. In: Harrison J., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J. & Brown, C.J. (Eds). The atlas of southern African birds. Johannesburg: BirdLife South Africa. pp. 480–481.

De Villiers, D. & Simmons, R.E. 1997. The high incidence and origin of two-egg clutches in a Damara Tern colony in south-western Namibia. *Madoqua* 19(2): 111-113

Elgood, J.H., Fry, C.H. and Dowsett, R.J. 1973. African migrants in Nigeria. *Ibis*. 115:1-45

Every, B. 1979. Damara Tern in Eastern Cape. *Bee-eater* 30(1):1-2

Frost, P.G.H. & Shaughnessy, G. 1976. Breeding adaptations of the Damara Tern. *Sterna balaenarum*. *Madoqua* 9(3):33-39

Frost, P. & Johnson, P. 1977. Seabirds on the Diamond Coast, South West Africa, December 1976. *The Cormorant* 3:13

Johnson, P. 1979. Third census of the Damara Tern at Elizabeth Bay, South West Africa, December 1978. *The Cormorant* 7:32

Johnson P and Frost P. Conserving the Damara Tern. *Optima*. 27:106-107

McLachlan, G.R. and Liversidge, R. 1978. Roberts Birds of South Africa. Cape Town: Trustees of the John Voelcker Bird Book Fund.

Oschadleus D. 2001 SAFRING news. Damara Tern migration. Africa - Birds & Birding 6(3):19

Randall, R.M. & McLachlan, A. Damara Terns breeding in the Eastern Cape, South Africa. 1982.

Reiss, L., Kruger, L.A. 1998. Monitoring of the Damara Tern *Sterna balaenarum* near Swakopmund, Namibia during the 1997/98 breeding season. Unpublished Report.

Sharmann M. 2005. Why conserve biodiversity. DG Research, personal reflections. http://www.egyptchm.org/chm/biodiversity/pdf/why_conserve_biodiversity.pdf

Siegfried, W.R. & Johnson, P. 1977. The Damara Tern and other seabirds on the Diamond Coast, South West Africa, December 1977.*Cormorant* 3:13

Simmons, R.E. & Cordes, I. 1998. Latitudinal trends, population size, and habitat preferences of Damara Terns *Sterna balaenarum* on Nambia's desert coast. *Ibis* 140:439-445

Simmons, R.E. & Cordes, I.. Size and Distribution of Damara Tern Populations on Namibia's Southern Coast. *The Cormorant* No 3 and No 2

Simmons, R.E. 1993a. A census of the desert-breeding Damara Tern *Sterna balaenarum* in Namibia. Proc. Pan-Afr. Orn. Congr. 8: 395-398

Simmons, R. 1993b. Catching and counting the elusive Damara Tern. *African Wildlife* 47:150-152

Simmons RE 2005 Declining coastal avifauna at diamond-mining site in Namibia: comparisons and causes. *Ostrich* 76: 97-103

Simmons RE 2005 Damara Tern In: Hockey PAR, Dean WRJ, Ryan PG (eds) *Roberts Birds of Southern Africa*. 7th edn. John Voelcker Bird Book Fund, Black Eagle Publishing, Cape Town, pp 464-465

Underhill, L.G., Cooper, J. and Waltner, M. 1980. The status of waders (Charadrii) and other birds in the coastal region of the southern and eastern Cape, summer 1978/89. Cape Town: Western Cape Wader Study Group.

Vincent, A.W. 1946. On the breeding habits of some African birds. *Ibis*. 88:48-67

Wallace, D.I.M. 1973. Seabirds at Lagos and in the Gulf of Guinea. *Ibis*. 115: 559-212

Watson, J. 1998. Battle for the Dunes: Éast coast' Damara Terns on the Alexandria Coastal Dunefield. *Africa-Birds and Birding*. 3(2): 55-59

Williams A.J., Ward V.L. and Underhill L.G. 2004. Waders respond quickly and positively to the banning of off-road vehicles from beaches in South Africa. *Wader Study Group Bulletin*. 104: 79-81.

Williams, A.J. & Myer, E.J. 1986. Damara terns: nonbreeding population and post-fledging feeding in the Lüderitz are of SWA/Namibia. *Lanioturdus* 22: 3-4

17.4.

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Protecting Damara Terns *Sterna balaenarum* from recreational disturbance in the Namib Desert increases breeding density and overall success

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Because resources and funds available for the conservation management of many threatened species are limited, it is important to determine the effectiveness of different conservation measures aimed at protecting threatened species. The globally Near Threatened Damara Tern *Sterna balaenarum* breeds on anthropogenically disturbed beaches on the central coast of Namibia. We assessed the effectiveness of conservation measures on the breeding numbers, densities and success of Damara Terns in a loose colony among small barchan dunes on the central Namibian coast. Nests were monitored daily during the 2001/02 and 2002/03 breeding seasons. Information notices were erected during the 2001/02 breeding season and vehicle access was restricted to prevent human disturbance in the colony during the 2002/03 season. Nest numbers and density doubled in the second season, but breeding success decreased significantly from 83% to 67%. This unexpected result probably arose from increased densities attracting more predators. Despite this decrease the protection measures increased the number of chicks hatching from the area by 71%. In conjunction with two previous studies of protection from off-road vehicles we conclude that Damara Terns benefit from reduced disturbance and prefer to nest on undisturbed beaches.

Introduction

The Damara Tern, one of the smallest members of the Sternidae, is a breeding endemic to Namibia. Only 2% of the global population breed outside the country, along the coastlines of South Africa and Angola (Crawford and Simmons 1997). The strip of coastline between Swakopmund and Walvis Bay, two coastal towns in central Namibia c. 40 km apart, has the greatest density of sea- and shorebirds roosting and feeding in southern Africa (Simmons et al. 1998a). The Damara Tern *Sterna balaenarum* nests adjacent to this strip, on the gravel plains that run parallel to the coast (Simmons et al. 1998b, Simmons 2005). The Damara Tern typically lays one egg in a small nondescript scrape on the ground, although two-egg clutches have been recorded on rare occasions (de Villiers and Simmons 1997, S Braby pers. obs.). Unlike other terns, Damara Terns breed in loose colonies with an average density of 1–8 nests per km^2 (Crawford and Simmons 1997). Damara Terns are mainland coastal breeders and prefer non-vegetated gravel or sandy plains in north-central regions and salt pans in southern regions (Simmons et al. 1998b, Simmons 2005). They often breed up to 5 km inland, but have been found to breed up to 11.5 km inland (Braby et al. 2001, Simmons 2005). The main breeding season starts in September and ends in April (JB pers. obs.), but nests with eggs occur as late as June (RJB pers. obs.) indicating that breeding extends over nine months. During non-breeding Damara Terns migrate to West Africa (Elgood 1982), but little is known about their exact non-breeding distribution and habitats. Three decades ago, the Damara Tern was listed as one of the 20 bird species breeding in South Africa most in need of conservation action (Siegfried et al. 1976). Subsequently, its threat status has varied between Globally Threatened to Near Threatened, its status in 2007 (BirdLife International 2007). In Namibia the species is listed as locally Near Threatened (Simmons and Brown in press).

Breeding Damara Terns are particularly vulnerable to human disturbance and conservation measures have been implemented to ensure their continued survival. Human disturbance in the Namib Desert is associated with recreational activities only, such as off-road vehicles (ORVs), quad-bikes, horse-riding and hiking. The densest population of breeding terns is found on the central Namibian coast during the austral summer, at the same time as the number of visitors to the area is greatest. Damara Terns have been subject to excessive disturbance and increased mortality during the breeding season in this area owing to off-road driving and quad-bike activity (Braby et al. 2001).

During November 2000, cable barriers were erected at a Damara Tern breeding colony at Caution Reef to prevent off-road vehicles (ORVs) from travelling across the sand and gravel plains where terns bred (Braby et al. 2001). However, it subsequently became apparent that large numbers of Damara Terns were breeding east of Caution Reef (Braby 1995) in an area known as the Horses Graveyard. Here terns were found breeding in gravel plains situated between dunes in an area popular with quad-bikers.

To determine the effectiveness of conservation measures, and to compare their success with that at the Caution Reef colony (Braby et al. 2001), the Horses Graveyard colony was monitored during the 2001/02 breeding season, when it was subjected to a high level of quad-bike traffic. The colony was again monitored during the following breeding season (2002/03) after interpretative sign boards had been erected and strict access restrictions had been enforced. This paper compares Damara Tern nest numbers and densities, breeding success, and causes of mortalities before and after these conservation measures were implemented.

Study area

The main study area at the Horses Graveyard colony covered 2.5 km² and occurred in the hyper-arid Namib Desert with rainfall of less than 15 mm per year (Günster 1995, Mendelsohn et al. 2003). It was located 4 km south of Swakopmund, on the central Namibian coast, and was centred on 22°42.500′ S, 14°32.300′ E (Figures 1 and 2). The study area was 3.7 km NNE of the Caution Reef colony and comprised a series of barchan, linear and crescent dunes separated by gravel plains in which the terns breed (Braby et al. 2001). Gravel plains were comprised of approximately 3 mm diameter, grey-coloured substrate, with little wind-blown material. By contrast the dunes had a much smaller sand particle diameter and sand transport during prevailing south-westerly winds could be high. The area was situated just south of a disused railway line, 3 km east of the sea, and runs parallel to the coast. The areas used by the breeding terns were devoid of vegetation.

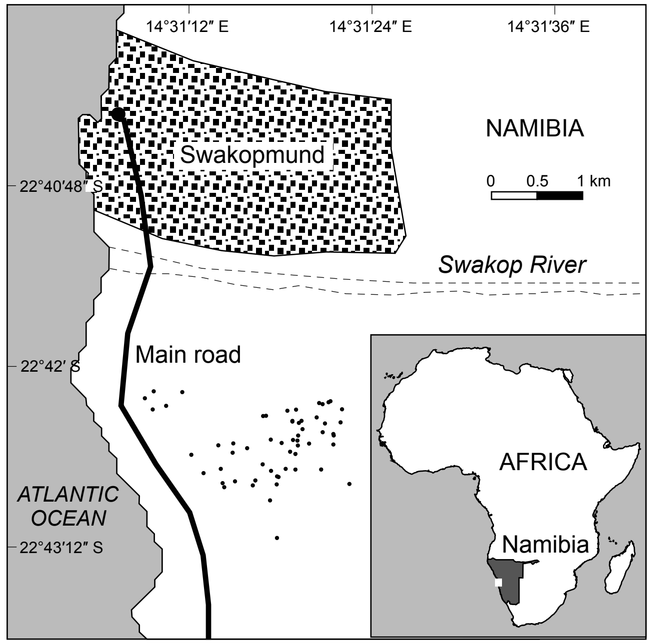

Figure 1: Damara Tern nesting distribution during the 2001/02 breeding season at the Horses Graveyard colony, central Namibia

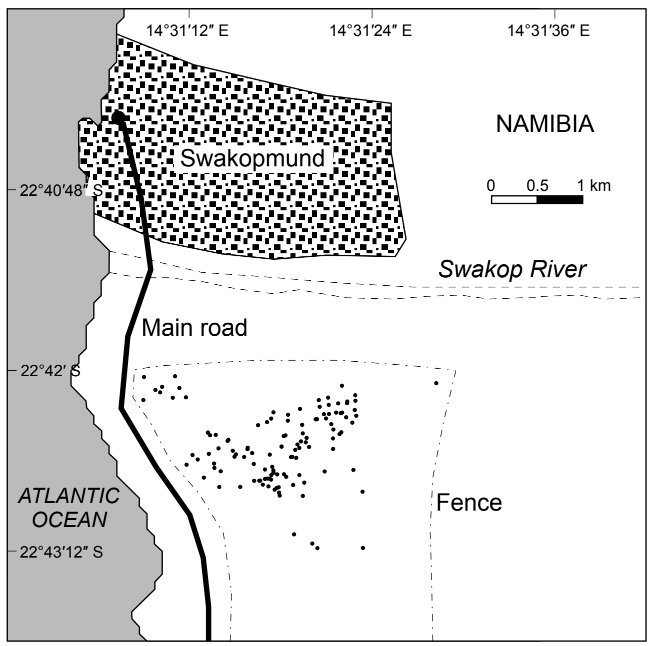

Figure 2: Damara Tern nest distribution during the 2002/03 breeding season at the Horses Graveyard colony, central Namibia, after the colony was fenced

Methods

The study was conducted between November and March over two breeding seasons, 2001/02 and 2002/03. One (or sometimes two) observers searched the study area on a quad-bike and recorded Damara Tern eggs and chicks and all vehicles or new tracks crossing the area. These searches were done daily; time of day varied from early morning to late afternoon. A record was kept of the date, time and location of all tracks and vehicles in the study area in December 2001. One route was followed through the study area to monitor breeding activities, but on occasion we explored new plains in search of potential nesting sites. A Global Positioning System (Garmin II) was used to record the exact location of each nest to an accuracy of c. 10 m. New nests were included into daily visit routines until the chick successfully hatched and was ringed or until nest failure. Breeding success was defined as the emergence and survival of a chick that moved away from its nest aged 3–4 d – a combination of hatch success and early survival. Thereafter we could not easily follow the cryptic chicks and be certain that they had perished if they were not subsequently found. The presence of potential predators such as Kelp Gulls *Larus dominicanus*, Rock Kestrels *Falco rupicolus* and black-backed jackals *Canis mesomalis* was recorded and failed nests were carefully examined for signs of predators, such as jackal tracks leading to empty nests. When known, the cause of nest failure was noted.

Information and interpretation sign boards were erected on 21 December 2001, in the middle of the 2001/02 breeding season. Signs of human disturbance continued to be monitored. Prior to the start of the 2002/03 breeding season, cable barriers were set up at entry points to the study area that were typically used by quad-bikes. Quad-bike tour companies were limited to one designated route and private bike enthusiasts were warned off the gravel plain areas. Information sheets highlighting the vulnerability of Damara Terns and the position of the breeding site were handed out to private quad-bikers and other tourists.

Results

Nest abundance and density

All nests found over the study period contained one egg. In the 2001/02 breeding season, the first nest was found on 2 November and, in total, 58 nests with eggs were found over a period of two and a half months (Figure 1). The breeding season ended on 23 January 2002, with no more eggs or chicks seen after this date. During the 2002/03 breeding season, 122 nests with eggs were found over a four-month period, with the first egg appearing on 24 October 2002 and breeding activity recorded until 23 February 2003 (Figure 2). Field work occurred before these dates and until March to ensure no further egg-laying. Nest abundance more than doubled from the 2001/02 season to the 2002/03 season. The density of nests in the 2.5 km^2 study area increased from 23 nests km^{-2} to 49 nests km^{-2}, indicating a 2.1-fold increase in breeding density following reduction in disturbance to the area. A possibility exists that nest density was larger in 2002/03 because of the longer season. We controlled for this by examining the same two-and-a-half month period (2 November to 23 January) in both seasons, when the relative densities were 23 nests km^{-2} in 2001/02 and 34 nests km^{-2} in 2002/03 indicating a 1.5-fold increase. There was no increase in the area occupied by the breeding terns. Assuming that each nest represented a different breeding pair, the number of nests in 2002/03 was significantly larger than in 2001/02 (comparison of two counts, $z = 4.78$, $P < 0.001$; Zar 1999). There were, in fact, at most 15 pairs that re-laid in 2002/03, so that at least 107 pairs bred that year. The breeding population was significantly larger in 2002/03 than in 2001/02 ($z = 3.81$, $P < 0.001$).

Human disturbance

In the 2001/02 season, new vehicle tracks were seen on a daily basis and sometimes more frequently. Vehicles were common on both the gravel plains and the dunes. Quad-bike tracks were most common. In November 2001, nine ORVs were observed driving through the study area at the start of the Damara Tern breeding season. During December 2001, 27 new sets of quad-bike tracks, five ORVs or their tracks and one set of horse tracks (which passed within 2 m of an active nest) were encountered during a 30-day period. About 30% of the quad-bike tracks were multiple tracks made by up to seven quad-bikes at a time. Tracks frequently passed within metres of nests with eggs, indicating that the bikers were unaware or uninterested in the tern nests. In six cases vehicle tracks were found within 5 m of an active nest, but no nests were destroyed by vehicles. There was no apparent decrease in vehicle disturbance after conspicuously placed information boards were erected along all borders of the study area on 21 December 2001.

During the 2002/03 season, after additional conservation measures had been implemented, quad-bike tours were only seen following the routes allocated to them. With one exception, tourists in ORVs drove only on dunes and always at safe distances from the nests. Only human or horse tracks were found in the vicinity of nests. There were no quad-bike tracks through the nesting area. Human disturbance was only witnessed on two occasions: two tourists walking through the gravel plains and an ORV vehicle driving through one breeding plain where a small colony of Damara Terns nested.

Table 1: The outcomes of Damara Tern nesting attempts during the 2001/02 and 2002/03 breeding seasons at the Horses Graveyard colony

Fate	2001/02	2002/03
Jackal predation	5 (8.6%)	20 (16.4%)
Egg addled	0 (0%)	2 (1.6%)
Chick found dead	0 (0%)	2 (1.6%)
Egg abandoned	2 (3.4%)	1 (0.8%)
Unknown fate[1]	3 (5.2%)	15 (12.3%)
Successful	48 (82.8%)	82 (67.2%)
Total nests with eggs	58	122

[1] 'Unknown fate' is defined by an egg or chick that was not found again but the cause of disappearance was unknown

Breeding attempts and overall breeding success

The number of successful breeding attempts increased from 48 nests in 2001/02 to 82 nests in 2002/03, a 71% increase (Table 1). However, as a percentage of nests initiated, successful nests decreased significantly from 83% (48 of 58) in 2001/02 to 67% (82 of 122) in 2002/03 ($\chi^2_1 = 4.1$, $P = 0.043$) (Table 1). Despite the significant decrease in the proportion of nests successful before and after protection, the increased number of nests in the second year resulted in 34 more chicks surviving until 4 d of age following the implementation of protective measures.

The reduced proportion of successful nests in 2002/03 was attributable to predation by black-backed jackals, as determined by tracks at failed nests. The number of nests failing from jackal predation increased four-fold from five nests in the 2001/02 season to 20 nests in 2002/03. In addition, a Rock Kestrel was periodically seen flying over the area during the 2002/03 breeding season; this species had not been observed during the previous season. A pair of Rock Kestrels was known to have bred in the vicinity of the study area in 2002/03, but had not been observed the previous year. Subsequently, in 2005, a Rock Kestrel was observed to take a Damara Tern chick (RJB pers. obs.). It is thus likely that a substantial proportion of the losses attributed to 'unknown fate' (Table 1) involved predation by this Rock Kestrel. Nest abandonment due to direct human disturbance decreased from two nests (3%) in the 2001/02 breeding season to one nest (0.8%) in 2002/03 (Table 1).

Discussion

Our results show that conservation interventions can be audited, and their benefits quantified, by measuring a number of biological parameters, such as breeding numbers, density and success of breeding, and intensity of disturbance before and after implementation of the interventions. In this study, there was a large increase in the number of Damara Terns breeding in the season following the exclusion of ORVs from the breeding area and the limitation of quad-bikes to fixed routes through it. Similarly, Braby et al. (2001) showed that nest density increased by 25% and that hatching success increased from 56% to 80% at the Caution Reef colony in the breeding season following exclusion of ORVs. At the southern limit of the species' breeding range, near Cape Agulhas, South Africa, all 11 pairs in the study area raised a chick to fledging in the year immediately following the ban on ORVs from beaches in South Africa (Williams et al. 2004). In the previous five years many pairs lost eggs or chicks during the midsummer holiday period due to disturbance attributable to ORVs. The similar results obtained in each of these three studies suggest that the protective measures played an important role in improving breeding participation and success. Non-breeding coastal seabirds also increased in number in study areas around the South African coast following the ban on ORVs (Williams et al. 2004).

In this study, once conservation measures were implemented, the breeding season lengthened from two-and-a-half to four months. There may be several reasons for the lengthening of the breeding season. Increased food resources to adults and chicks, known to be critical in tern breeding ecology (Nisbet 1978, Monaghan et al. 1989), could account for this change. At both De Mond and in this study, the breeding season started earlier after disturbance was eliminated, so that protection may have contributed to the lengthening of the season. Breeding earlier provides fledglings with a longer period of preparation for migration (Williams et al. 2004).

Once vehicle disturbance was eliminated, it was found that predation was an unexpected determinant of breeding success. The reduced breeding success in the second year was attributable to increased levels of predation by jackals and probably by the arrival of a new predator, the Rock Kestrel. Ecological factors such as these could not have been addressed through these conservation measures, but in hindsight may be expected for a ground-nesting species reliant on cryptic, well-spaced nests. Predation levels can increase naturally as nest density increases (Newton 1998), so it is useful to examine how much higher these densities were than typically encountered on the Nambian coast.

Nest densities in both seasons (23–49 nests km^{-2}) were higher than previously recorded along Namibia's coast (1–15 nests km^{-2}) (Simmons et al. 1998b) and at the nearby Caution Reef colony (12–15 nests km^{-2}) (Braby et al. 2001). The high densities at Horses Graveyard cannot be attributed to breeding habitat limitation, as there are vast areas of gravel plains available, nor can it be an anti-predator strategy as predation increased with higher tern densities.

Measuring the effectiveness of conservation measures is an essential but often untested step in the protection of any threatened biome, habitat or species. Managers should not simply assume that conservation efforts will be successful or that testing the effectiveness of measures is unnecessary, even if managers fear this will reveal that resources used and expenses incurred were not justified. We recommend that funders of conservation projects set aside a portion of the funding for auditing the effectiveness of conservation interventions. In this case we demonstrated that the conservation measures enacted were effective, a result consistent with observations at two other sites in Namibia and South Africa.

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References

BirdLife International. 2007. *Sterna balaenarum*. Available at http://www.birdlife.org/datazone/species/index.html?action=SpcHTMDetails.asp&sid=3282&m=0) [accessed June 2009].

Braby RJ, Shapiro A, Simmons RE. 2001. Successful conservation measures and new breeding records for Damara Terns *Sterna balaenarum* in Namibia. *Marine Ornithology* 29: 81–84.

Braby RJ. 1995. Effects of human disturbance on Damara Tern breeding success in the central Namib. Unpublished report. Swakopmund: Ministry of Environment and Tourism.

Crawford RJM, Simmons RE. 1997. Damara Tern. In: Harrison JA, Allan DG, Underhill LG, Herremans M, Tree AJ, Parker V, Brown CJ (eds), *The atlas of southern African birds,* vol. 1: *Non-passerines*. Johannesburg: BirdLife South Africa. pp 480–481.

de Villiers D, Simmons RE. 1997. The incidence and origin of two-egg clutches in a Damara Tern colony in southwestern Namibia. *Madoqua* 19: 111–113.

Elgood JH. 1982. *The birds of Nigeria*. Checklist No. 4. London: British Ornithologists' Union.

Günster A. 1995. Grass cover distribution in the central Namib – a rapid method to assess regional and local rainfall patterns of arid regions? *Journal of Arid Environments* 29: 107–114.

Mendelsohn J, Jarvis A, Roberts C, Robertson T. 2003. *Atlas of Namibia: a portrait of the land and its people*. Cape Town: David Philip.

Monaghan P, Uttley JD, Burns MD, Thaine C, Blackwood J. 1989. The relationship between food supply, reproductive effort and breeding success in Arctic Terns *Sterna paradisaea*. *Journal of Animal Ecology* 58: 261–274.

Nisbet ICT. 1978. The dependence of fledging success on egg size, parental performance and egg composition in Common and Roseate Terns, *Sterna hirundo* and *S. dougalli. Ibis* 120: 207–215.

Newton I. 1998. *Population limitation in birds*. London: Academic Press.

Siegfried WR, Frost PGH, Cooper J, Kemp AC. 1976. *South African red data book – Aves.* South African National Scientific Programmes Report No. 7. Pretoria: Council for Scientific and Industrial Research.

Simmons RE. 2005. Damara Tern. In: Hockey PAR, Dean WRJ, Ryan PG (eds), *Roberts birds of southern Africa* (7th edn). Cape Town: Trustees of the John Voelcker Bird Book Fund. pp 464–465.

Simmons RE, Boix-Hinzen C, Barnes KN, Jarvis AM, Robertson A. 1998a. *Important Bird Areas of Namibia*. In: Barnes KN (ed.), *The Important Bird Areas of southern Africa.* Johannesburg: BirdLife

South Africa. pp 295–332.
Simmons RE, Brown CJ. In press. *Birds to watch in Namibia: red, rare and peripheral species.* Windhoek: National Biodiversity Programme.
Simmons RE, Cordes I, Braby R. 1998b. Latitudinal trends, population size and habitat preferences of the Damara Tern *Sterna balaenarum* on Namibia's desert coast. *Ibis* 140: 439–445.
Williams AJ, Ward VL, Underhill LG. 2004. Waders respond quickly and positively to the banning of off-road vehicles from beaches in South Africa. *Wader Study Group Bulletin* 104: 79–81.
Zar JH. 1999. *Biostatistical analysis* (4th edn). Upper Saddle River: Prentice-Hall.

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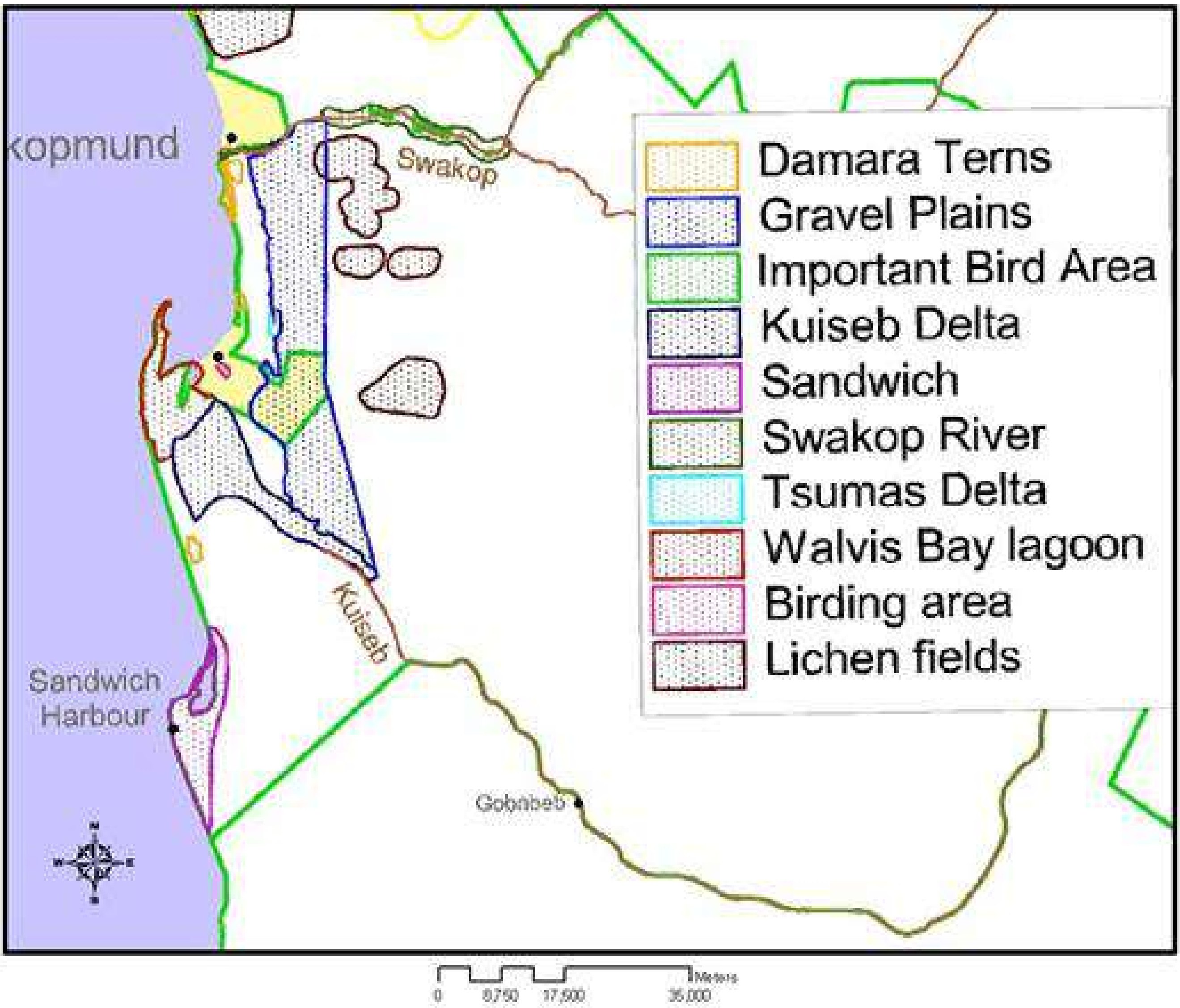
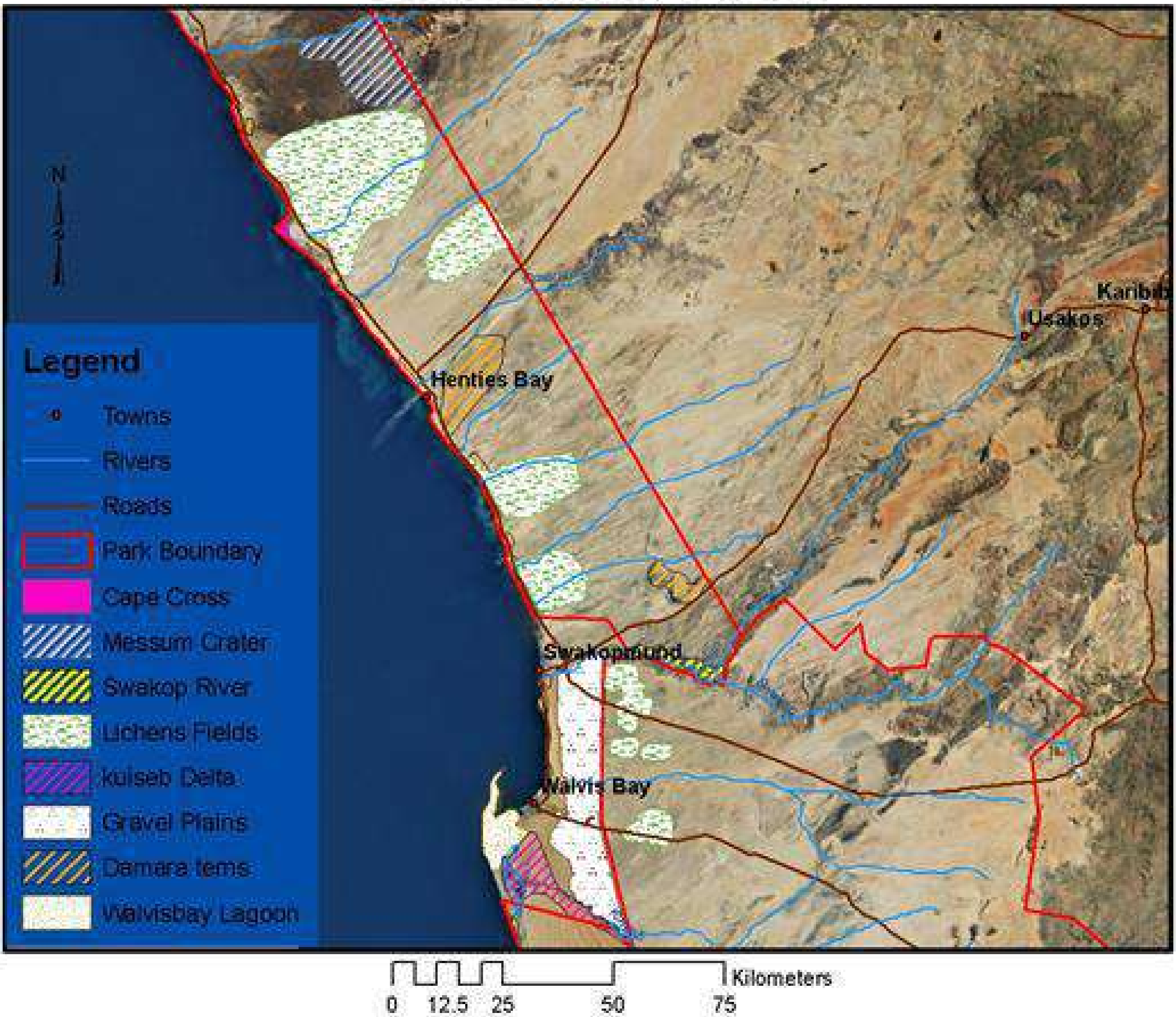
17.5.

CONSERVANCY AREAS



kopmund
Swakop
Kuiseb
Sandwich Harbour
Gobabeb
Damara Terns
Gravel Plains
Important Bird Area
Kuiseb Delta
Sandwich
Swakop River
Tsumas Delta
Walvis Bay lagoon
Birding area
Lichen fields
Meters
0
8,750
17,500
35,000

Conservancy Areas



18.

APPENDIX O:

VEGETATION BASELINE SURVEY

VEGETATION BASELINE SURVEY

FOR

DESERT ROSE DEVELOPMENT

REPORT PREPARED BY

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FOR

NATIONAL ENVIRONMENTAL HEALTH CONSULTANTS

JULY 2014

VEGETATION BASELINE SURVEY FOR DESERT ROSE DEVELOPMENT

CONTENT

List of Tables and Figures

Abbreviations

B	-	Beach habitat
CITES	-	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CR	-	Critically Endangered (IUCN threat category)
DD	-	Data Deficient (IUCN category)
DHG	-	Dune - Hummock - Gravel habitat
EN	-	Endangered (IUCN threat category)
HKBC	-	Herta Kolberg Botanical Consulting
IUCN	-	International Union for Conservation of Nature
LC	-	Least concern (IUCN category)
MET	-	Ministry of Environment and Tourism
NE	-	Not Evaluated (IUCN category)
NEHC	-	National Environmental Health Consultants
NT	-	Near Threatened (IUCN category)
SA	-	Survey Area
VU	-	Vulnerable (IUCN threat category)
WIND	-	National Herbarium of Namibia, Windhoek

1. Summary

A desktop study revealed a potential 159 plant species in the vicinity of the study area, including six protected by law, 33 with restricted distribution and none threatened. During a field survey six plant species were found of which four have restricted distribution, none are threatened or protected by law. Two habitat types - Beach and Dune-Hummock-Gravel - were identified, both of which were evaluated as having "moderate" sensitivity. Compared with surrounding areas, the study area is more densely vegetated. The importance of plants in this harsh environment was observed and highlighted. It is recommended that as much natural habitat as possible should be retained if the development goes ahead.

2. Background

Desert Rose Pty. plans to develop a stretch of coastal land between Swakopmund and Langstrand for residential and recreational purposes, including a convention centre and golf course. National Environmental Health Consultants (NEHC) has been contracted to obtain environmental clearance for this development. NEHC contracted Herta Kolberg Botanical Consulting (HKBC) to prepare a vegetation baseline study for the affected area. This report summarises the findings of a vegetation survey in the area.

3. Terms of Reference

A basic vegetation survey was required from this consultant. Plant species expected to occur in the area must be identified through desktop study and this verified during fieldwork on the ground. It included identifying and describing habitats present and the plants contained therein, assessing habitat sensitivity, listing plants of special importance and compiling this information in a report.

4. Approach

4.1 Desktop Study

Plants expected to occur in the coastal area between Swakopmund and Walvis Bay were identified from the consultant's personal database of plant collections and supplementing this with information from the National Herbarium (WIND) collection. Plant nomenclature follows Kolberg & Craven (2014).

4.2 Field Survey

On 24 June 2014 the area proposed for development of Desert Rose was visited and walked to identify all the plant species found there at the time. Herbarium specimens were taken to verify the identity of these species. Different habitats were identified visually and the plants in each determined.

4.3 Status

The IUCN status (threatened) of species was taken to be that in Loots (2005) and Craven and Loots (2002). The IUCN Protected Area category of the area was obtained from MET (2009), Dudley (2008) and the IUCN website (http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/). The distribution status of species present - endemic, rare - was determined from the consultant's personal database. Legal status is according to the guidelines of the Nature Conservation Ordinance (Nature Conservation Ordinance 4 of 1975) and Appendix II of CITES as well as the repealed forestry legislation (Preservation of Trees and Forests Ordinance No. 37 of 1952 and the Forest Act 72 of 1968) since the Forest Act 12 of 2000 has not yet come into force and has no regulations listing protected species. It is, however, likely that species that were protected under the old legislation will remain protected once the new law comes into force.

4.4 Sensitivity Rating

A relative sensitivity rating of the identified habitats was conducted using the criteria in Table 1.

Table 1: System used for sensitivity rating

Habitat level criteria		**points per habitat**
1. Diversity		
1.1	contains >50% of total species recorded	3
1.2	contains 30 – 50% of total species recorded	2
1.3	contains <30% of total species recorded	1
2. Abundance/Rarity		
2.1	habitat surface area in survey area (SA) <30% of total SA and rare outside SA	6
2.2	habitat surface area in SA <30% of total SA, moderate occurrence outside SA	5
2.3	habitat surface area in SA <30% of total SA, common occurrence outside SA	4
2.4	habitat surface area in SA 30 – 50% of total SA and rare outside SA	3
2.5	habitat surface area in SA 30 – 50 % of total SA, moderate occurrence outside SA	2
2.6	habitat surface area in SA 30 - 50% of total SA, common occurrence outside SA	1
3. Physical complexity		
3.1	high diversity of structures, micro-habitats, soils …	3
3.2	moderate diversity of structures, micro-habitats, soils …	2
3.3	low diversity of structures, micro-habitats, soils …	1
4. Resource flow		
4.1	facilitating high resource flow	2
4.2	facilitating moderate resource flow	1
4.3	high moisture retention	3
4.4	medium moisture retention	2
4.5	low moisture retention	1
5. Other habitat traits		
5.1	keystone structure/s present	5
5.2	>50% of species perennial	5
5.3	31 - 50% of species perennial	3
5.4	≤30% of species perennial	1
6. Restoration potential		
6.1	not possible, containing high percentage of long-lived species	3
6.2	not possible, physical environmental structure cannot be recreated	3
6.3	partly possible	1
Species level criteria		**points per species**
7. Endemism		
7.1	endemic to central coast of Namibia	5
7.2	endemic to coast of Namibia	4

7.3	endemic to Namibia	3
7.4	endemic to Namibia and 1 other country	2
7.5	endemic to Namibia and 2 other countries	1
8. Conservation / legal status		
8.1	Red List species – IUCN category CR	5
8.2	Red List species – IUCN category EN	4
8.3	Red List species – IUCN category VU	3
8.4	IUCN category NT or DD	2
8.5	protected under Nature Conservation Ordinance	3
8.6	formerly protected under Forest Legislation	3
8.7	CITES listed	2
9. Abundance / Rarity		
9.1	recorded at < 30% of all sampling points	3
9.2	recorded at 30 – 50% of all sampling points	2
9.3	present in 1 habitat only	3
9.4	average abundance at all sampling points $\leq$ 5% crown cover	3
9.5	average abundance at all sampling points $\leq$ 10% crown cover	2
10. Ecological services		
10.1	keystone species	3
10.2	perennial forage species	3
10.3	ephemeral forage species	2
10.4	soil stabiliser (wind erosion)	2
10.5	other (specify)	2

Some of the above criteria required some subjective judgement, like the abundance or rarity of the particular habitat outside the survey area in point 2. or keystone status of species in 10.1. Under point 8.5, species were rated using repealed forestry legislation (Preservation of Trees and Forests Ordinance No. 37 of 1952 and the Forest Act 72 of 1968) since the Forest Act 12 of 2000 has not yet come into force and has no regulations listing protected species. It is likely that the species protected under the repealed legislation will remain protected. Listing on CITES was rated lower than listing under the Nature Conservation Ordinance or Forest Act, because CITES only regulates trade across Namibian borders and not removal or destruction like the latter.

The total number of points for each habitat type was calculated separately for the habitat criteria and the species criteria. The two categories were then given equal weight by multiplying the habitat category score by total number of species found. The two scores were added and the range between the theoretically possible lowest and highest score divided into 4 equal categories to represent low (0 to 100 points), moderate (101 to 201 points), high (202 to 303 points) and critical (304 to 405 points) habitat sensitivity.

4.5 Mapping

Mapping was done using Google Earth (http://www.google.com/earth/index.html) and Diva (http://www.diva-gis.org/) Geographical Information Systems.

5. Results

5.1 Desktop Study

The flora of the central Namib has been the topic of many studies, however, most of these merely list species for a certain area without any quantitative data (presence/absence only). Ecological studies in the area which quantify the occurrence of species are usually at a coarse scale and do not give information specific enough for the management of small areas such as the envisioned Desert Rose development (Burke & Strohbach 2000). The SA falls into the Southern Namib vegetation type according to Giess (1971) and the Southern Desert or Southern Namib following Mendelsohn *et al.* (2010).

The Desert Rose area falls into the Dorob National Park and therefore is classified as National Park – IUCN category 2. The beach area is zoned as recreational area within the national park and access by vehicle is allowed. The fenced-off Damara Tern breeding area in the eastern part of the SA is classified as Strict Nature Reserve - IUCN category 1a (MET 2009).

A study of herbarium specimens at the National Herbarium of Namibia (Windhoek) on record for the coast between Swakopmund and Walvis Bay and an area approximately 30 km inland (quarter-degree squares 2214DA and 2214DC) was made. This revealed that 159 plant taxa (Appendix A) have been recorded of which six are protected by legislation, one listed on Appendix II of CITES, none classified as threatened (categories CR, EN or VU) according to IUCN criteria, 17 have distributions restricted to the Namib desert, 16 are endemic to Namibia and 21 species are not indigenous to Namibia (aliens). Since quarter-degree square 2214DA includes the Swakop river with higher plant diversity due to fresh underground and ephemeral water, these figures are an overestimate for the Desert Rose area.

5.2 Field Survey

Six plant species were found in the area during the field survey (Table 2). Images of these plants can be viewed in Appendix B.

Table 2: Plant species found in Desert Rose area

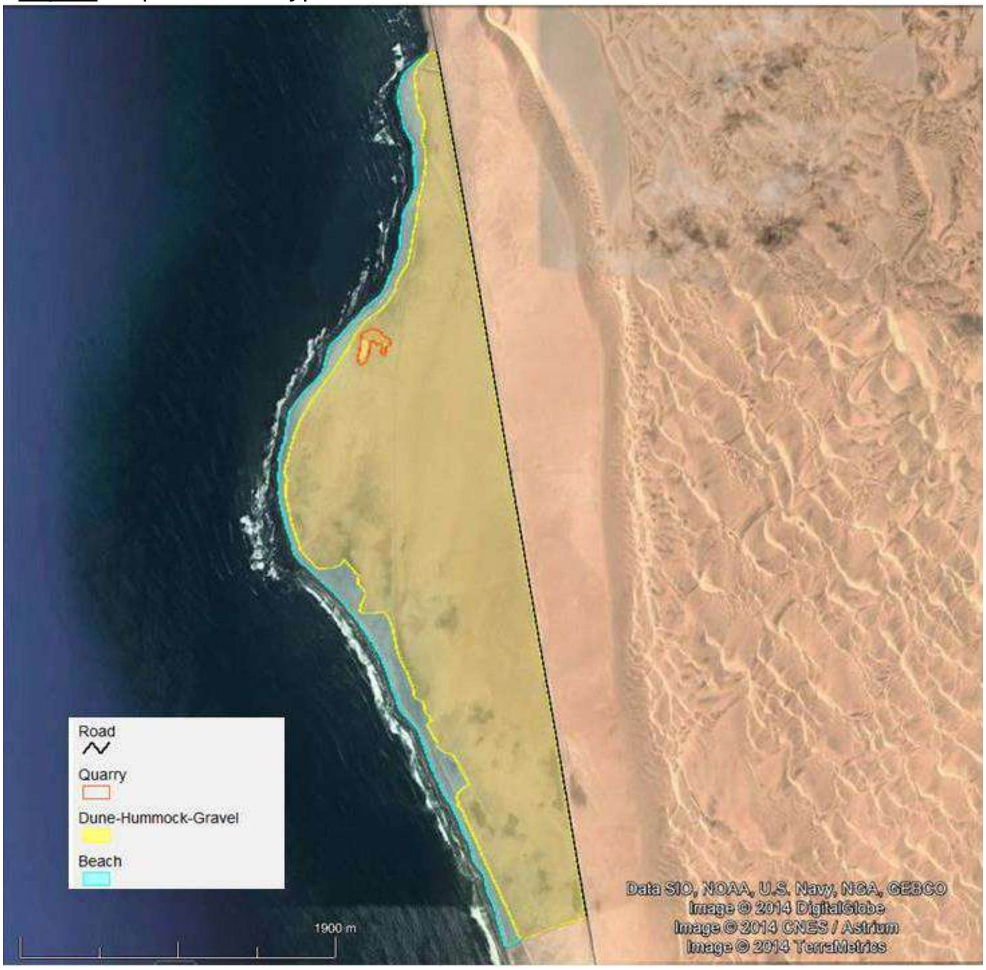
Species	Common Name*	Distribution	IUCN category**	Legislation***	Habitat****	
					B	DHG
AIZOACEAE						
Psilocaulon salicornioides (Pax) Schwantes		Namibian near-endemic	LC		X	X
Trianthema hereroensis Schinz	Dune Succulent (E); Dünenpolster (G)	Endemic to Namibia; Namib species	LC			X
AMARANTHACEAE						
Arthraerua leubnitziae (Kuntze) Schinz	Pencil Bush (E); Bleistiftpflanze (G); saris, |haisaris (K)	Endemic to Namibia; Namib species	LC		X	X
Salsola sp.	Ganna (A); Saltwort, Salt Bush (E); Brackbush (G)				X	X
Sarcocornia natalensis (Bunge ex Ung.-Sternb.) A.J.Scott	Glasswort (E)	Entire southern African coast	NE		X	
ZYGOPHYLLACEAE						
Zygophyllum clavatum Schltr. & Diels		Namibian near-endemic; Namib species	LC		X	X

* A = Afrikaans; E = English; G = German; K = Khoekhoegowab
** LC = Least Concern; NE = Not Evaluated
*** F = Forestry Legislation; P = Nature Conservation Ordinance; II = CITES Appendix II
**** B = Beach; DH = Dune - Hummock

The habitat in the survey area is relatively uniform. Based on topography, a distinction can be made between the Beach habitat (B) and the inland Dune-Hummock-Gravel habitat

(DHG). The quarry site has been disturbed and no longer represents a natural habitat or houses any plants. Table 2 shows the species found in each habitat and Fig. 1 a map of the habitat types in the SA.

Fig. 1: Map of habitat types identified



5.3 Status

Two of the species found are endemic to Namibia and the Namib while two are near-endemic to Namibia, of which one is also confined to the Namib desert. One species is found on the entire southern African coast. The species of *Salsola* could not be determined because the plants were not flowering or fruiting at the time. It may be a near-endemic coastal/Namib species or one with restricted distribution.

None of the plant species found are classified as "threatened" according to IUCN categories (VU - vulnerable, EN - endangered, CR - critically endangered). *Sarcocornia natalensis* has not been evaluated, but given its wide distribution it is not likely to be threatened. Without specific identification the *Salsola* sp. cannot be assigned an IUCN category (IUCN 2013).

None of the plants found in this survey are protected by Namibian legislation or listed on CITES.

5.4 Sensitivity Rating

The sensitivity rating of the two identified habitats was determined as moderate (Table 3).

Table 3: Sensitivity rating of identified habitats

Habitat	Weighted sensitivity rating score	Sensitivity
Beach	172	MODERATE
Dune - Hummock - Gravel	186	MODERATE

6. Discussion

6.1 General

The SA is located at the extreme northern tip of the Southern Namib vegetation type which is characterised by sand dunes. Although the vegetation in this vegetation type is sparse and not very species-rich, it is of great importance in this desert area to other biota (insects, mammals, birds) as source of food and shelter as also observed during this survey. In this rather hostile environment with strong winds, mobile sands and saline soils, only highly specialised plants (and other biota) will survive. *Trianthema hereroensis*, also found in the SA, is restricted to this vegetation type and the populations east and south-east of the SA are particularly large and form a considerable proportion of the global extent of this species. The large plants of *Arthraerua leubnitziae* so close to the ocean as they occur in the Beach habitat is quite unusual along Namibia's coast.

Compared to similar habitat outside the SA, like the area to its immediate south, the SA is more densely vegetated. The SA therefore must surely be one of the very few refuges for other biota in the coastal stretch between Walvis Bay and Swakopmund. A development as that planned for Desert Rose would destroy this refuge leaving ever decreasing options of survival for other biota.

The SA is by no means pristine and disturbance in the form of a quarry, efforts at sand extraction and vehicle tracks are present. It is, however, in a more natural state than any other coastal areas in the immediate surrounds.

6.2 Habitats

a Beach Habitat

This habitat makes up approximately 11.3 % of the total SA and is the area between the ocean and between 50 and 200 m above the high water mark (Fig. 1). This habitat consists of mobile sand and depressions inland from the high water mark are characteristic for most of the length of this habitat (Fig. 3). These depressions house most of the vegetation in this habitat. The sand is relatively moist and periodically (during spring tides) the depressions may be flooded with sea water.

For this habitat five species (83% of the total number of species found in the survey) were recorded (Table 2). The vegetation consists of salt tolerant perennial shrubs which form dense hummocks, thus binding mobile sands. *Sarcocornia natalensis* was found only in this habitat and not further inland. One species is endemic to the Namibian part of the Namib Desert while two are near-endemic to Namibia of which *Zygophyllum clavatum* occurs in the entire coastal stretch of the Namib Desert from Angola to South Africa and *Psilocaulon salicornioides* is found in Namibia and South Africa but not restricted to the Namib Desert (Table 2).

The vegetation in this habitat serves to bind detritus and mobile sands that get moved by both wave and wind action. A large number of invertebrates (insects) were observed on and around these plants and tracks of small mammals (rodents) were seen (Fig. 2). Besides stabilising the substrate, these hummock-forming plants play a key role in the function of this habitat through providing food and shelter for other biota as well as returning nutrients to the soil from decomposing detritus (Table 4).

Fig. 2: A honey bee visiting *Psilocaulon salicornioides* (left) and tracks of rodents around *Salsola* sp. (right).

Table 4: Sensitivity rating of Beach habitat

Habitat level		**Species level**	
1. Diversity	3	7. Endemism	8
2. Abundance/Rarity	4	8. Conservation / legal status	0
3. Physical complexity	1	9. Abundance / Rarity	22
4. Resource flow	5	10. Ecological services	28
5. Other habitat traits	5		
6. Restoration potential	1		
TOTAL	19		58
Grand TOTAL (weighted)	**MODERATE**		**172**

Fig. 3: Typical Beach habitat

b Dune - Hummock - Gravel Habitat

This habitat makes up approximately 88.2 % of the total SA and is the area between the Beach habitat and the higher sand dunes to the east (Fig. 1). In the SA this habitat lies between the Beach habitat and the Swakopmund - Walvis Bay tar road. This habitat consists of a mixture of highly mobile sand forming low dunes and hummocks and gravel plains with a cover of pebbles and rocks of various sizes (Fig. 4). It is difficult to clearly delimit the dunes and hummocks from the gravel plains on a map because they are rather small areas and change over time due to the moving sands. For this reason it was decided to include these landforms in one habitat.

Fig. 4: Typical Dune-Hummock-Gravel habitat

For this habitat five species (83% of the total number of species found in the survey) were recorded (Table 2). The vegetation consists of perennial shrubs which form hummocks, binding mobile sands. *Trianthema hereroensis* was found only in this habitat and only in the most south-eastern corner of the SA which is closest to the high dunes east of the tar road. Two species are endemic to the Namibian part of the Namib Desert while two are near-endemic to Namibia of which *Zygophyllum clavatum* occurs in the entire coastal stretch of the Namib Desert from Angola to South Africa and *Psilocaulon salicornioides* is found in Namibia and South Africa but not restricted to the Namib Desert (Table 2).

The vegetation in this habitat serves to bind detritus and mobile sands that get moved by wind action. A large number of invertebrates (insects) were observed on and around these plants and tracks of small mammals (rodents) were seen. Nearly the entire area of this habitat in the SA is fenced off as Damara Tern breeding site. This habitat (and the low, western slopes of the high dunes to the east) houses the densest vegetation in this otherwise sparsely vegetated coastal area. Besides stabilising the substrate, these hummock-forming plants play a key role in the function of this habitat through providing food and shelter for other biota as well as returning nutrients to the soil from decomposing detritus (Table 5).

Table 5: Sensitivity rating of Dune-Hummock-Gravel habitat

Habitat level		**Species level**	
1. Diversity	3	7. Endemism	12
2. Abundance/Rarity	0	8. Conservation / legal status	0
3. Physical complexity	2	9. Abundance / Rarity	23
4. Resource flow	4	10. Ecological services	31
5. Other habitat traits	10		
6. Restoration potential	1		
TOTAL	20		66
Grand TOTAL (weighted)	**MODERATE**		**186**

7. Recommendations

- No plant species that fall into the IUCN threatened categories or that are protected by Namibian legislation, which would require obtaining a permit prior to their removal, were found. The entire Desert Rose area, however, falls into a protected area (national park) and the Ministry of Environment and Tourism needs to be contacted to clarify the implications of this.

- Large plants occurring in the SA should be retained because of their value in the ecosystem and since they are very old and will not easily be replaced.

- Areas earmarked for conservation in the proposed development, should be increased or expanded. These should retain natural substrate (not paved or planted with alien species) and natural vegetation

- It should be considered to landscape the planned golf course with local plants and retaining as much natural substrate as possible.

- During construction, personnel on site must be made aware of the environmental issues and strict control over vehicle movement must be exercised.

8. References

Burke, A. & Strohbach, B.J. 2000. Review: Vegetation Studies in Namibia. *Dinteria* 26:1-24.

Craven, P. & Loots, S. 2002. Namibia. In: Golding, J. (ed.), Southern African Plant Red Data Lists. *Southern African Botanical Diversity Network Report* 14:61 - 92.

Dudley, N.(ed.). 2008. Guidelines for applying protected area management categories. IUCN, Gland. pp. 106.

Giess, W. 1971. A preliminary vegetation map of South West Africa. *Dinteria* 4:5 – 114.

IUCN Standards and Petitions Subcommittee. 2013. Guidelines for Using the IUCN Red List Categories and Criteria. Version 10.1. Prepared by the Standards and Petitions Subcommittee. Downloadable from http://www.iucnredlist.org/documents/RedListGuidelines.pdf

Kolberg, H. & Craven, P. 2014. Plants of Namibia. http://herbaria.plants.ox.ac.uk/bol/namibia

Loots, S. 2005. Red Data Book of Namibian Plants. *Southern African Botanical Diversity Network Report* 38. SABONET, Pretoria and Windhoek. 124 pp.

Mendelsohn, J., Jarvis, A., Roberts, C. & Robertson, T. 2010. Atlas of Namibia. A portrait of the land and its people. Sunbird Publishers, Cape Town. 220 pp.

Ministry of Environment and Tourism (MET). 2009. Final Draft Management and Development Plan for the Central Coast Park of the Namib-Skeleton Coast National Park. Unpublished Report. For the Period 2010 to 2015. 111 pp.

Appendix A: Plant species expected to be found in the Desert Rose development area

Species	Distribution	IUCN category*	Legislation**
ACANTHACEAE			
Blepharis grossa (Nees) T.Anderson	Namibian near-endemic		
Blepharis obmitrata C.B.Clarke	also in South Africa		
Monechma cleomoides (S.Moore) C.B.Clarke	Namibian near-endemic		
Petalidium variabile (Engl.) C.B.Clarke	Endemic to Namibia		
AIZOACEAE			
Aizoanthemum dinteri (Schinz) Friedrich	Endemic to Namibia		
Aizoanthemum galenioides (Fenzl. ex Sond.) Friedrich	Endemic to Namibia; Namib species		
Brownanthus kuntzei (Schinz) Ihlenf. & Bittrich	Near Endemic to Namibia; Namib species	NE	
Galenia africana L.			
Galenia namaensis Schinz		NE	
Galenia papulosa (Eckl. & Zeyh.) Sond.			
Galenia sarcophylla Fenzl. ex Harv. & Sond.		NE	
Mesembryanthemum guerichianum Pax		NE	
Opophytum cryptanthum (Hook.f) Gerbaulet	Near Endemic to Namibia; Namib species	NE	
Psilocaulon salicornioides (Pax) Schwantes			
Tetragonia arbuscula Fenzl.		NE	
Tetragonia reduplicata Welw. ex Oliv.	Namibian near-endemic; Namib species	NE	
Tetragonia verrucosa Fenzl.		NE	
Trianthema hereroensis Schinz	Endemic to Namibia; Namib species		
AMARANTHACEAE			
Arthraerua leubnitziae (Kuntze) Schinz	Endemic to Namibia; Namib species		
Atriplex lindleyi Moq. subsp. inflata (F.Muell.) Paul G.Wilson	Not indigenous to Namibia	NE	
Atriplex semibaccata R.Br.	Not indigenous to Namibia	NE	
Atriplex suberecta I.Verd.		NE	
Atriplex vestita (Thunb.) Aellen		NE	
Chenopodium murale L.	Not indigenous to Namibia	NE	
Hermbstaedtia spathulifolia (Engl.) Baker	Endemic to Namibia		
Nelsia quadrangula (Engl.) Schinz	also in South Africa	NE	
Salsola angolensis Botsch.	also in South Africa	DD	
Salsola aphylla L.f.		DD	
Salsola gemmifera Botsch.		DD	
Salsola luederitzensis Botsch.		DD	
Salsola nollothensis Aellen		NE	
Salsola parviflora Botsch.	Endemic to Namibia	DD	
Salsola procera Botsch.	Endemic to Namibia; Namib species	DD	
Salsola seydelii Botsch.	Endemic to Namibia	DD	
Salsola swakopmundi Botsch.	Endemic to Namibia; Namib species	DD	
Sarcocornia natalensis (Bunge ex Ung.-Sternb.) A.J.Scott var. affinis (Moss) O'Callaghan		NE	
Suaeda merxmuelleri Aellen	Namibian near-endemic	DD	
Suaeda plumosa Aellen		NE	
APIACEAE			
Deverra denudata (Viv.) Pfisterer & Podlech subsp. aphylla (Cham. & Schltr.) Pfisterer & Podlech		NE	

Species	Distribution	IUCN category*	Legislation**
APOCYNACEAE			
Gomphocarpus filiformis (E.Mey.) D.Dietr.			
Orthanthera albida Schinz	Namibian near-endemic		
ASTERACEAE			
Arctotis venusta T.Norl.	also in South Africa	NE	
Bidens pilosa L.	Not indigenous to Namibia	NE	
Cotula anthemoides L.		NE	
Cotula coronopifolia L.		NE	
Dauresia alliariifolia (O.Hoffm.) B.Nord. & Pelser	Namibian near-endemic		
Dicoma capensis Less.	also in South Africa	DD	
Doellia cafra (DC.) Anderb.		NE	
Felicia anthemidodes (Hiern) Mendonça		NE	
Flaveria bidentis (L.) Kuntze	Not indigenous to Namibia	NE	
Gazania jurineifolia DC. subsp. scabra (DC.) Roessler	Namibian near-endemic	NE	
Geigeria ornativa O.Hoffm. subsp. ornativa var. ornativa			
Helichrysum argyrosphaerum DC.		NE	
Helichrysum roseo-niveum Marloth & O.Hoffm.	Namibian near-endemic	NE	
Myxopappus hereroensis (O.Hoffm.) Källersjö	Endemic to Namibia; Namib species		
Nidorella resedifolia DC. subsp. resedifolia			
Ondetia linearis Benth.	Endemic to Namibia		
Pechuel-Loeschea leubnitziae (Kuntze) O.Hoffm.	also in South Africa	NE	
Pentzia calva S.Moore	Namibian near-endemic	NE	
Pseudognaphalium luteo-album (L.) Hilliard & B.L.Burtt	Not indigenous to Namibia	NE	
Senecio engleranus O.Hoffm.	Endemic to Namibia		
Senecio flavus (Decne.) Sch.Bip.			
Sonchus oleraceus (L.) L.	Not indigenous to Namibia	NE	
Tripteris microcarpa Harv. subsp. microcarpa		NE	
Tripteris microcarpa Harv. subsp. septentrionalis (T.Norl.) B.Nord.		NE	
Verbesina encelioides (Cav.) Benth. & Hook.f ex A.Gray	Not indigenous to Namibia	NE	
Xanthium strumarium L.	Not indigenous to Namibia	NE	
BORAGINACEAE			
Euploca ovalifolia (Forssk.) Diane & Hilger		NE	
Heliotropium curassavicum L.	Not indigenous to Namibia	NE	
Heliotropium oliveranum Schinz		NE	
Heliotropium tubulosum E.Mey. ex DC.		NE	
BRASSICACEAE			
Coronopus integrifolius (DC.) Spreng.	Not indigenous to Namibia	NE	
BURSERACEAE			
Commiphora saxicola Engl.	Namibian near-endemic		
CAMPANULACEAE			
Lobelia thermalis Thunb.		NE	
CARYOPHYLLACEAE			
Spergularia media (L.) C.Presl	Not indigenous to Namibia	NE	
CLEOMACEAE			
Cleome foliosa Hook.f		NE	
COLCHICACEAE			

Species	Distribution	IUCN category*	Legislation**
Hexacyrtis dickiana Dinter	Namibian near-endemic; Namib species		
CRASSULACEAE			
Cotyledon orbiculata L.		NE	
CUCURBITACEAE			
Acanthosicyos horridus Welw. ex Hook.f	Namibia Angola and maybe NW South Africa		P
Citrullus ecirrhosus Cogn.	Namibian near-endemic		
Dactyliandra welwitschii Hook.f	Namibian near-endemic		
CYPERACEAE			
Cyperus esculentus L.		NE	
Cyperus laevigatus L.		NE	
Cyperus marginatus Thunb.		NE	
Eleocharis schlechteri C.B.Clarke		NE	
Scirpoides dioecus (Kunth) Browning		NE	
EBENACEAE			
Euclea pseudebenus E.Mey. ex A.DC.		NE	F
EUPHORBIACEAE			
Euphorbia gregaria Marloth	Namibian near-endemic		II
Euphorbia phylloclada Boiss.	Namibian near-endemic		
FABACEAE			
Adenolobus pechuelii (Kuntze) Torre & Hillc. subsp. pechuelii	Namibian near-endemic		
Crotalaria colorata Schinz	Endemic to Namibia; Namib species	NE	
Erythrina decora Harms	Namibian near-endemic		F
Faidherbia albida (Delile) A.Chev.			F
Parkinsonia africana Sond.		NE	F
Tephrosia dregeana E.Mey.		NE	
FRANKENIACEAE			
Frankenia pulverulenta L.		NE	
JUNCACEAE			
Juncus rigidus Desf.		NE	
LIMEACEAE			
Limeum myosotis H.Walter			
LORANTHACEAE			
Tapinanthus oleifolius (J.C.Wendl.) Danser	also in South Africa		
MALVACEAE			
Hermannia affinis K.Schum.		NE	
Hermannia modesta (Ehrenb.) Mast.		NE	
Malva parviflora L.	Not indigenous to Namibia	NE	
MOLLUGINACEAE			
Glinus lotoides L. var. lotoides	Not indigenous to Namibia	NE	
Hypertelis salsoloides (Burch.) Adamson			
OXALIDACEAE			
Oxalis pes-caprae L. var. pes-caprae		NE	
PLUMBAGINACEAE			
Dyerophytum africanum (Lam.) Kuntze	also in South Africa	NE	
POACEAE			
Anthephora pubescens Nees		NE	
Aristida parvula (Nees) De Winter	Namibian near-endemic	NE	
Cladoraphis spinosa (L.f.) S.M.Phillips	also in South Africa	NE	

Species	Distribution	IUCN category*	Legislation**
Cynodon dactylon (L.) Pers.	Not indigenous to Namibia	NE	
Entoplocamia aristulata (Hack. & Rendle) Stapf	Namibian near-endemic	NE	
Eragrostis annulata Rendle ex Scott-Elliot		NE	
Eragrostis dinteri Stapf		NE	
Eragrostis echinochloidea Stapf	also in South Africa	NE	
Eragrostis nindensis Ficalho & Hiern		NE	
Eragrostis superba Peyr.		NE	
Fingerhuthia africana Lehm.			
Lolium rigidum Gaudich	Not indigenous to Namibia	NE	
Odyssea paucinervis (Nees) Stapf		NE	
Panicum repens L.			
Paspalum vaginatum Sw.		NE	
Pennisetum foermerianum Leeke	Endemic to Namibia		
Phragmites australis (Cav.) Steud.			
Poa annua L.	Not indigenous to Namibia	NE	
Pogonarthria fleckii (Hack.) Hack.			
Polypogon monspeliensis (L.) Desf.	Not indigenous to Namibia	NE	
Polypogon viridis (Gouan) Breistr.	Not indigenous to Namibia	NE	
Puccinellia acroxantha C.A.Sm. & C.E.Hubb.	Not indigenous to Namibia	NE	
Sporobolus nebulosus Hack.	also in South Africa	NE	
Sporobolus virginicus (L.) Kunth			
Sporobolus welwitschii Rendle		NE	
Stipagrostis ciliata (Desf.) De Winter var. capensis (Trin. & Rupr.) De Winter			
Stipagrostis hermannii (Mez) De Winter	Namibian near-endemic; Namib species		
Stipagrostis schaeferi (Mez) De Winter	Namibian near-endemic; Namib species	NE	
Stipagrostis subacaulis (Nees) De Winter	Namibian near-endemic; Namib species	NE	
Stipagrostis uniplumis (Licht.) De Winter var. uniplumis			
Tragus berteronianus Schult.			
Tricholaena monachne (Trin.) Stapf & C.E.Hubb.			
Triraphis ramosissima Hack.	Namibian near-endemic	NE	
POLYGONACEAE			
Polygonum plebeium R.Br.		NE	
POTAMOGETONACEAE			
Potamogeton pectinatus L.		NE	
Zannichellia palustris L. subsp. palustris	Cosmopolitan	NE	
RUPPIACEAE			
Ruppia maritima L.	Cosmopolitan	NE	
SALVADORACEAE			
Salvadora persica L.		NE	
SCROPHULARIACEAE			
Camptoloma rotundifolium Benth.	Namibian near-endemic	NE	
Jamesbrittenia canescens (Benth.) Hilliard var. canescens	Namibian near-endemic	NE	
Manulea conferta Pilg.	Namibian near-endemic	NE	
SOLANACEAE			
Lycium horridum Thunb.		NE	
Lycium oxycarpum Dunal		DD	
Lycium tetrandrum Thunb.		NE	

Species	Distribution	IUCN category*	Legislation**
Nicotiana glauca Graham	Not indigenous to Namibia	NE	
TAMARICACEAE			
Tamarix usneoides E.Mey. ex Bunge		NE	F
VAHLIACEAE			
Vahlia capensis (L.f.) Thunb.			
ZYGOPHYLLACEAE			
Tribulus excrucians Wawra		NE	
Tribulus zeyheri Sond.		NE	
Zygophyllum clavatum Schltr. & Diels	Namibian near-endemic; Namib species		
Zygophyllum longistipulatum Schinz	Endemic to Namibia	NT	
Zygophyllum simplex L.			
Zygophyllum stapffii Schinz	Namibian near-endemic; Namib species		

* DD = Data Deficient; NE = Not Evaluated; NT = Near Threatened
** F = Forestry Legislation; P = Nature Conservation Ordinance; II = CITES Appendix II

Appendix B: Images of plant species found at Desert Rose study area

Psilocaulon salicornioides

Trianthema hereroensis

	
Arthraerua leubnitziae	
	
Salsola sp.	

Sarcocornia natalensis

Zygophyllum clavatum

19.

APPENDIX P:

ARCHAEOLOGICAL AND HERITAGE ASSESSMENT OF THE SAND ROSE PROJECT

QRS

J. & J. KINAHAN, Archaeologists
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15 August 2014

National Environmental Health Consultants
P. O. Box 8416
SWAKOPMUND

Attention: Ms Felecia Schoeman
NEHC Project No: 2014/031/C
PO 100012 (14/7/2014)

QRS Job 209

Archaeological and heritage desk assessment of Sand Rose project

1. Introduction

Sand Rose Investments (Pty) Ltd intends to develop a multi-component project on a property located 24 km north of Walvis Bay and 7 km south of Swakopmund. The property lies between the B2 highway and the coastal high water mark, in an area bounded by the following geographical coordinates1:

-22.725972	14.509993	-22.725972	14.543455
-22.792673	14.509993	-22.792673	14.543455

National Environmental Health Consultants (NEHC) has been appointed to carry out an Environmental Impact Assessment (EIA) of the proposed development in order to comply with the provisions of the Environment Management Act 7 of 2007. In response to concerns raised during the mandatory Public Participation Process, NEHC commissioned Quaternary Research Services (QRS) to provide a desk assessment of possible impact risks posed by the development in respect of sites and remains protected under the provisions of the National Heritage Act 27 0f 2004.

The desk study presented below is based on a consultation of existing inventories of known sites/remains in the project locality, as well as a cursory inspection of the property carried out on 6th August 2014. The report presents an estimation of site significance and vulnerability, and an estimation of impact risk on chance/previously unrecorded finds based on existing data from adjacent parts of the Namib coast. The report considers palaeontological, archaeological and historical remains, the latter including historic shipwrecks as defined by Paragraph 57 (1) of the National Heritage Act.

2. Physical setting

The area of the proposed project footprint is extensively covered by mobile windblown sand, partially stabilized as thinly vegetated hummock dunes, and by a broad sandy beach, lying above a mainly horizontally-bedded shoreline of sedimentary rock with limited outcrop of Damara metasediments and

1 The extent of the project area is inferred from a diagram supplied by NEHC and may not represent the precise limits of the property.

related rock. Much of the area within the proposed project footprint is enclosed by a barrier erected to protect a suspected breeding and roosting site used by the rare and endemic Damara Tern *Sternula balaenarum.*

A number of well-established tracks run between the high water mark and the westernmost hummock dunes. A short stretch of surfaced road leads from the B2 highway to the beach at the northern end of the property. There is also a large disused borrow pit with associated spoilheaps, a relic of the railway between Swakopmund and Walvis Bay, that used to run along the shoreline. The railway earthworks, running from north to south through the property, are still clearly discernible, with localized concentrations of steam engine cinders noticeable in the sand on either side of the earthworks.

Visible over a limited part of the seaward edge of the hummock dune belt is a discontinuous accumulation of what appear to be *Donax rogersi*, the now extinct precursor on this shoreline of the prevailing sandy beach mollusc *Donax serra.* The shoreline adjacent to these accumulations is no longer sandy, and this, together with their elevation at approximately 4m above mean sea level indicates that the shell accumulations represent a relic of the Eemian beach associated with the sea-level rise of between 5 and 7 m which occurred Marine Isotope Stage 5, in the period 110 to 130 000 years ago.

3. Known sites/remains

The records of the National Museum of Namibia and the Namib Desert Archaeological Survey contain no entries of palaeontological or archaeological sites within the area of the proposed development. On the basis of these records it would appear that there are no sites or remains such as would be protected under the provisions of the National Heritage Act. Supporting this view is the fact that the property includes no natural sources of fresh water, a basic requirement for human settlement.

Although the proposed development will not in its initial stage extend to seaward of the high water mark, it was considered prudent to determine whether any known shipwrecks lay in the sea adjacent to the property. To this end, the records of the National Museum of Namibia and those of the Walvis Bay port authorities (archival records held in Pretoria, South Africa) were consulted. Among these records, wooden vessels predominate and of these very little generally survives at the site of the sinking. The two sets of records consulted list more than 25 ships lost in the general area of Swakopmund and Walvis Bay. However, there is no record of any vessel in the immediate vicinity of the proposed Sand Rose development.

4. Observations

The indications that the property contains no archaeological sites or remains were confirmed by the brief site visit on 6th August, which also revealed no trace of wreckage on the beach adjacent to the site. The earthworks associated with the old railway line do not appear to be of heritage value. The relic of the Eemian beach mentioned above, while it does contain sub-fossil molluscan remains, would not be considered as a palaeontological site under the provisions of the National Heritage Act. Thus, the observations made at the site during the site visit generally confirmed the records of known sites and remains, indicating that the site of the proposed development is not a significant heritage site.

5. Assessment

In terms of it's vulnerability to possible impacts related to the development of the Sand Rose project, the area will in all likelihood loose the remains of the Eemain beach and the railway earthworks. Since these are not considered to be significant, the impact of the development would be low.

Since the records consulted do not identify any specific shipwreck in the vicinity of the proposed development it is considered that the project would pose a low threat of impact to the remains of shipwrecks in the area. It is noted that in its initial phase the project will not in any case have an impact below the low water mark.

6. Recommendations

The proposed Sand Rose project appears to have no implications for sites and remains protected under the provisions of the National Heritage Act. However, it is recommended that project staff and contractors are made aware of the provisions of the Act regarding the protection of heritage sites and remains, in particular that such sites and remains should be immediately reported to the National Heritage Act. To this end, it is further recommended that the project Environmental Management Plan (EMP) should adopt the chance finds procedure set out below to assist the process of reporting.

7. Chance finds procedure

Areas of proposed mining and infrastructure development are subject to heritage survey and assessment at the planning stage. These surveys are based on surface indications alone, and it is therefore possible that sites or items of heritage significance will be found in the course of development work. Personnel and contractor heritage induction is intended to sensitize people so that they may recognize heritage "chance finds" in the course of their work. The procedure set out here covers the reporting and management of such finds.

The "chance finds" procedure covers the actions to be taken from the discovery of a heritage site or item, to its investigation and assessment by a trained archaeologist or other appropriately qualified person. The "chance finds" procedure is intended to ensure compliance with the relevant provisions of the National Heritage Act (27 of 2004), especially Section 55 (4): *" a person who discovers any archaeological …. object ……must as soon as practicable report the discovery to the Council".* The procedure of reporting set out below must be observed so that heritage remains reported to the NHC are correctly identified in the field.

7.1 RESPONSIBILITIES

Operator	To exercise due caution if archaeological remains are found
Foreman	To secure site and advise management timeously
Superintendent	To determine safe working boundary and request inspection
Archaeologist	To inspect, identify, advise management, and recover remains

7.2 PROCEDURE

Action by person (operator) identifying archaeological or heritage material

a) If operating machinery or equipment: **stop work**
b) Identify the site with flag tape
c) Determine GPS position if possible
d) Report findings to foreman

Action by foreman

a) Report findings, site location and actions taken to superintendent
b) Cease any works in immediate vicinity

Action by superintendent

a) Visit site and determine whether work can proceed without damage to findings
b) Determine and mark exclusion boundary
c) Site location and details to be added to AH GIS for field confirmation by archaeologist

Action by archaeologist

a) Inspect site and confirm addition to AH GIS
b) Advise NHC and request written permission to remove findings from work area
c) Recovery, packaging and labelling of findings for transfer to National Museum

In the event of discovering human remains

a) Actions as above
b) Field inspection by archaeologist to confirm that remains are human
c) Advise and liaise with NHC and Police

d) Recovery of remains and removal to National Museum or National Forensic Laboratory, as directed.

I hope this report will be found satisfactory and look forward to your further instructions
Yours sincerely,

J. Kinahan PhD MSAIE & ES

Partner

20.

APPENDIX Q:

SOIL, LAND AND LAND USE ASSESSMENT

Rehab Green cc
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Report No: RG/2014/03/13/1
Date: 17 October 2014
Status: Draft

REPORT

Soil, Land Capability and Land Use Assessment of the footprint of the proposed Desert Rose residential and business development near Swakopmund, Namibia

Requested By

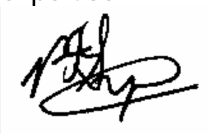
National Environmental Health Consultants

Compiled By

Rehab Green Monitoring Consultants CC
Environmental and Rehabilitation Monitoring Consultant cc
P.I. Steenekamp (Cert.Sci.Nat.)

Declaration of Independence

I, Piet Steenekamp, ID 6802115009089, hereby declare that I have no conflict of interest related to the work of this report. Specially, I declare that I have no personal financial interests in the property and/or development being assessed in this report, and that I have no personal or financial connections to the relevant property owners, developers, planners, financiers or consultants of the development. I declare that the opinions expressed in this report are my own and a true reflection of my professional expertise.



P.I. Steenekamp

Date: 17 October 2014

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1. INTRODUCTION

1.1 Project background

The Client is planning a mixed residential and business development situated between Swakopmund and Walvis Bay, Namibia (Figure 1). The development will be known as Desert Rose, situated approximately 7km south of Swakopmund and 25 km north of Walvis Bay, covering an area of approximately 356 ha.

Figure 1: Regional setting of the proposed Desert Rose Development area

1.2 Scope of work

Rehab Green Monitoring Consultants cc was requested by National Environmental Health Consultants (NEHC) to conduct a detailed soil, land capability and land use assessment of the proposed Desert Rose Development footprint in order to comply with applicable environmental legislation.

1.3 Applicable Legislation

The proposed development triggers the Environmental Management Act, 2007 (Act No.7 of 2007), promulgated in the Government Gazette of the Republic of Namibia on 27 December 2007 (The Act). The Act serves to:

"promote the sustainable management of the environment and the use of natural resources by establishing principles for decision making on matters affecting the environment; to establish the Sustainable Development Advisory Council; to provide for the appointment of the Environmental Commissioner and environmental officers; to provide for a process of assessment and control of activities which may have significant effects on the environment; and to provide for incidental matters."

Principles of environmental management that is applicable to the proposed development and subsequent requires the assessment of soils, land capability and land uses is stipulated in The Act in Section 3, subsection (2), points (e), (f), (g) and (l) namely:

"(e) assessments must be undertaken for activities which may have a significant effect on the environment or the use of natural resources;

(f) sustainable development must be promoted in all aspects relating to the environment;

(g) Namibia's cultural and natural heritage including, its biological diversity, must be protected and respected for the benefit of present and future generations; and

(l) damage to the environment must be prevented and activities which cause such damage must be reduced, limited or controlled."

An activity applicable to the proposed development that requires a soil, land capability and land use assessment are listed in The Act in Section 27, subsection (2), point (a) namely:

"(a) land use and transformation."

1.4 Assumptions

Neither a detailed development plan nor a development outline or footprint was obtained from NEHC in an electronic spatial format such dwg, dxf or shapefile. However, 4 coordinates and a hand drawn development outline on Google Earth satellite imagery were received. The 4 coordinates were used to create a study area which was extended up to the coastline to the west. The soil, land capability and land use assessment was conducted on this study area and it was assumed that it covers the total proposed development footprint.

2. STUDY AIMS AND OBJECTIVES

In order to identify the optimal and other possible land uses of an area, the **land capability** of the area needs to be assessed. Land capability depends directly on the physical and chemical properties of the soil resource together with climatic conditions.

Once the physical properties of the soil resource are determined and mapped, the area can be categorized and subdivided in land capability classes. Optimal and other possible land uses can then be assigned to each land capability class. Only thereafter the impact of land transformation due to a specific activity such as a residential development can be determined. The study objectives were to:

- Conduct a detailed soil assessment of the proposed development footprint;
- Classify and map soil forms according to the South African Taxonomic Soil Classification System, 1991;
- Derive and map land capability classes based on soil properties;
- Identify soil properties related to wetness to enable the delineation of wetland zones based on guidelines of the South African Department of Water Affairs;
- Map all current land uses;
- Determine optimal and other possible land uses; and
- Determine all possible impacts by the proposed activities and provide associated mitigation measures.

3. SOIL STUDY AND PROPOSED DEVELOPMENT AREAS

The 4 coordinate points which were provided by NEHC to serve as an indication of the extent of the proposed Development Area is shown as green dots in Figure 2. The 4 coordinate points were connected and extended up to the coastline to the west. The subsequent area is indicated with a solid yellow line and is referred to as the **Soil Study Area**, comprising a total of 407.01 ha. The Soil Study Area stretches basically from the coastline to the west up to the D2 tar road to the east and it is assumed that it includes the total proposed Development footprint.

Figure 2: Soil Study and Development Area

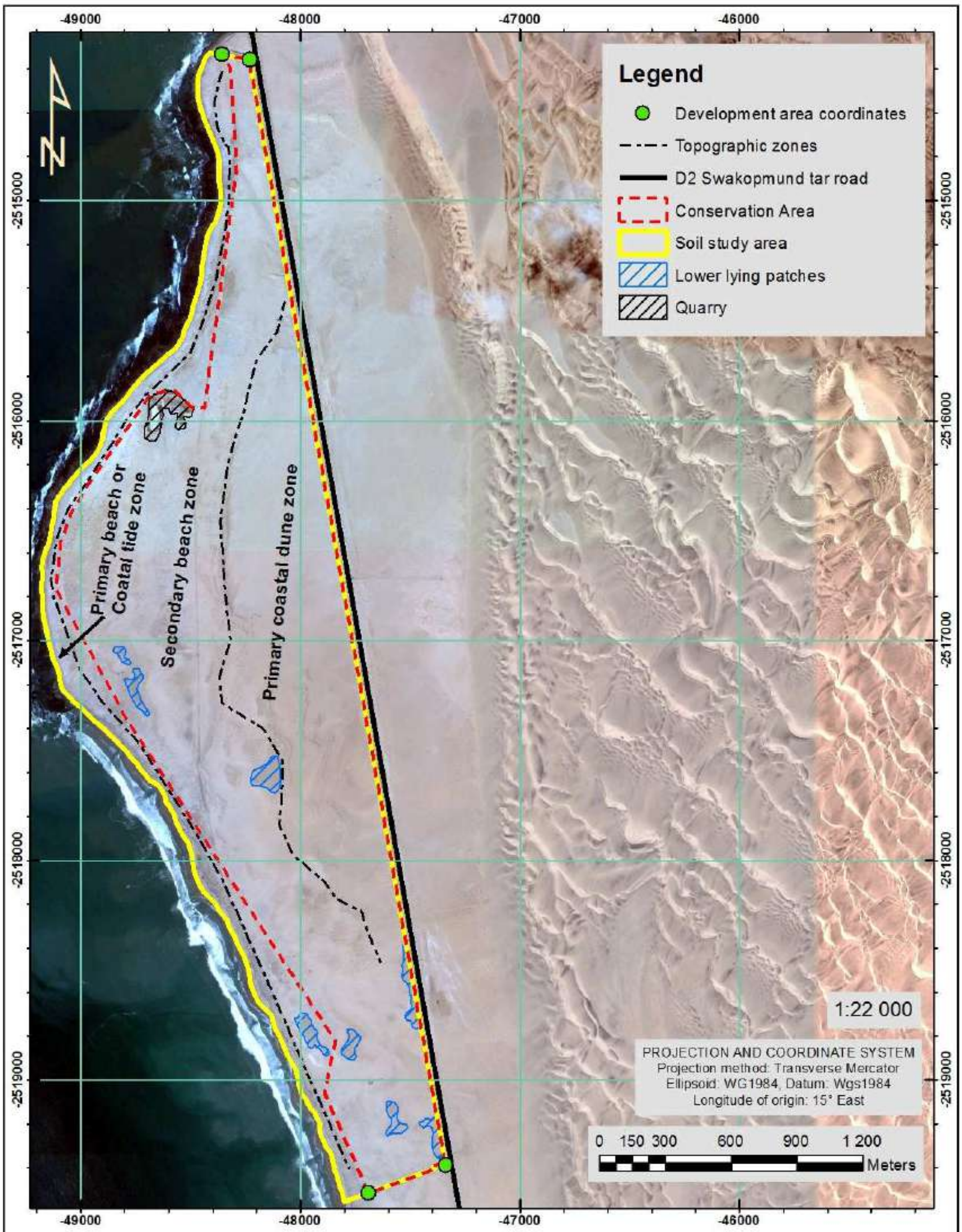


Figure 2: Soil Study and Development Area

The Soil Study Area was broadly subdivided in 3 zones based on topography, namely a primary beach or coastal tide zone to the west, a secondary beach zone (central) and a primary coastal dune zone to the east. The zone transitions are indicated with a dashed black line in Figure 2.

The Conservation Area within the Soil Study Area is indicated with a dashed red line and comprises a total area of 340.7 ha. The Conservation Area is fenced off with a cable fence.

The position of an existing open pit which appears to be a former rock quarry or mine is hatched black (Figure 2). The majority of the pit floor is covered with water.

No rivers or drainage lines occurs in the Soil Study Area. A few lower lying patches, hatched in blue, were observed during the soil assessment. The patches were dry during the time of the soil assessment but it appeared that water accumulates there during certain coastal tide fluctuations.

4. METHODOLOGY

4.1 Field preparation procedures

Geographic Information System (GIS) software from ESRI (Environmental Systems Research Institute) called ArcGIS-ArcMap was used to process all available data for accurate surveying and map compilations. The extent and location of the proposed Development Area footprint was generated as explained section 3.

A grid of field observation points were generated at a density of 150 m x 150 m across the Soil Study Area. The coordinates of the observation points were calculated and loaded on a Geographic Positioning System (GPS) to accurately locate the position of the observation points in the field. Large scale field maps (1:5000 scale) showing the Soil Study Area and observation points, superimposed on Google Earth satellite imagery were printed to use during the field assessment.

4.2 Field procedure and soil classification

A permit was obtained from the Ministry of Environment and Tourism, Directorate Parks and Wildlife Management on 27 August 2014 to enter the Conservation Area. The field observation points were randomly assessed. The soils were investigated by means of auger holes to a depth of 1200 mm or to refusal. The soils were described and classified according to the South African Taxonomic Soil Classification System (Soil Classification Working Group, 2nd edition 1991). The system of soil classification is explained in Appendix A.

The following procedure was followed to note soil properties and classify soils accordingly:

i) Identify applicable diagnostic horizons by noting the physical properties such as:

- Effective depth (depth of soil suitable for root development);
- Colour (in accordance with Munsell colour chart);
- Texture (refers to the particle size distribution);
- Structure (aggregation of soil particles into structural units);
- Mottling (alterations due to continued exposure to wetness);
- Concretions (cohesion of minerals into hard fragments);

- Leaching (removal of soluble constituents by percolating water);
- Gleying (reduction of ferric oxides under anaerobic conditions, resulting in grey, low chroma soil colours); and
- Illuviation of colloidal matter from one horizon to another, resulting in the development of grey sandy E-horizons and grey clay G-horizons.

ii) Determine the appropriate soil Form and soil Family according to the above properties.

The soil properties that were used to map fairly homogeneous soil types are discussed in Appendix B.

4.3 Soil sampling and analyses

Due to the pure sandy texture of the soil and the extreme arid climatic conditions the fertility status of the soils has a negligible impact on the study objective and soils were therefore not sampled and analysed.

4.4 Land capability assessment

Land capability was assessed according to the definitions outlined in the guidelines for the rehabilitation of mined land by the Chamber of Mines of South Africa and Coaltech Research Association (2007). The definitions are practical and apply effectively to any activity that may cause a moderate to severe impact to the soil resource with subsequent significant land transformation. The land capability classes are defined as follows:

Class I: Wetland

Although all land performs hydrological functions, that termed Wetland is particularly important in regulating subsurface storage and drainage of excess precipitation on a continual rather than sporadic basis. It is made up of vleis, swamps, marshes, peat-bogs and the like. There is usually a water table present at shallow depth in the soil with the result that it is difficult or impossible to recover soil material for later use because heavy machinery becomes bogged down, unless the soils are drained. Land assigned to Class I: Wetland, has one of the following characteristics:

- a diagnostic organic (O) horizon at the surface
- a horizon that is gleyed throughout more than 50 percent of its volume and is significantly thick, occurring within 75 cm of the surface.

Class II: Arable land

Land which conforms to all of the following requirements is designated as Class II: Arable:

- does not qualify as wetland
- has soil that is readily permeable[4] to the roots of common cultivated plants throughout a depth of 0.75 m from the surface
- has a soil pH value between 4,0 and 8,4
- has electrical conductivity of the saturation extract less than 400mS/m at 25^{o}C and an exchangeable sodium percentage less than 15 through the upper 0,75 m of soil
- has a permeability of at least 1,5 mm per hour in the upper 0.5 m of soil

- has less than 10 percent by volume of rocks or pedocrete fragments larger than 100 mm in diameter in the upper 0,75 m of soil
- has a slope (in percent) and erodibility factor[5] (K) such that their product is less than 2,0
- occurs under a climate regime which permits, from soils of similar texture and adequate effective depth (0,75 m), the economic attainment of yields of adapted agronomic or horticultural crops that are at least equal to the current national average for those crops, or
- is either currently being irrigated successfully or has been scheduled for irrigation by the Department of Water Affairs.

Class III: Grazing land

Grazing land conforms to all of the following requirements:

- does not qualify as wetland or as arable land
- has soil or soil-like material, permeable to the roots of native plants, that is more than 0.25 m thick and contains less than 50 % by volume of rocks or pedocrete fragments larger than 100 mm diameter
- supports or is capable of supporting a stand of native or introduced grass species or other forage plants utilisable by domesticated livestock or game animals on a commercial basis.

Class IV: Wilderness land

This is land which has little or no agricultural capability by virtue of being too arid, too saline, too steep or too stony to support plants of economic value. Its uses lie in the fields of recreation and wildlife conservation. It does, however, also include watercourses, submerged land, built-up land and excavations. Wilderness land is defined by exclusion, namely:

- land which does not qualify as wetland, arable land or grazing land.

4.5 Dry land crop production potential

The classification of dry land crop production potential of soils was based on physical soil properties noted during auger observations, such as effective soil depth, texture, terrain unit, slope, soil wetness and disturbances. The effective soil depth and texture class are the main soil characteristics that determined the dry land crop production potential. The criteria applied for the classification of the crop production potential of soils are as follows:

- **High** – well-drained and moderately well-drained loamy sand to sandy clay loam soils with an effective depth deeper than 900 mm.
- **Moderate** - well-drained and moderately well-drained loamy sand to sandy clay loam soils with an effective depth of 600- 900 mm.
- **Low** - well-drained and moderately well-drained sandy or clay soils.
- **Very low** – Imperfectly to poorly drained, grey, sandy soils showing evidence of periodic percolating water tables, or black and grey clay soils showing evidence of poor internal drainage, any soils in arid climatic conditions, shallow rocky areas and eroded areas.

4.6 Wetland and riparian delineation

Wetland and riparian zones were delineated according to the practical field procedure for the identification and delineation of wetlands and riparian areas (Department of Water Affair and Forestry, 2005). Four indicators were used in the study to delineate wetland and riparian zones, namely:

- Terrain unit;
- Soil form;
- Soil wetness; and
- Wetland and riparian vegetation.

Further details on the delineation of wetland areas are included in Appendix C.

4.7 Land use mapping

The localities and extents of land use practices were surveyed during the time of the soil assessment.

4.8 Erodibility evaluation

Erodiblity was broadly assessed based on soil texture, slope and the inherent stability of the parent rock (geology) from which the soil originated.

Low: Soils with stable physical and chemical properties which occur on flat to gentle slopes to ensure low erosion susceptibility in the natural state. Few erosion protection measures are necessary.

Moderate: Soils with low to moderately unstable physical or chemical properties or soils occurring on moderate to steep slopes. Sheet and rill erosion often occur in the natural state but may become severe when these soils are disturbed or due to any misuse such as overgrazing. Erosion protection measures are necessary.

High: Soils with unstable physical and chemical properties or soils occurring on very steep slopes or soils subject to continuing strong windy conditions. Rill and donga erosion dune formation often occur in the natural state and will become severe during any disturbance or misuse. Specialised erosion protection measures are necessary.

4.9 Map compilations

The field data was captured in shapefile format (shp) and processed and stored in a Geographic Information System called ArcGIS. The maps are compiled in a map extendable document format (mxd) and exported to Jpeg format. The shapefiles can be exported to a dxf or dwg format for CAD users. The shapefiles, dxf and dwg formats are available on request.

The maps were generated in a projected coordinate system using the longitude of origin (LO) coordinate system based on the 15° East meridian, WG1984 Ellipsoid and WGS 1984 Datum.

4.10 Approach to impact assessment and management

The EIAMAP[1] is a comprehensive tool used to manage the negative environmental impacts associated with mining and related activities and consists of two key aspects.

Firstly, the EIAMAP includes a full impact assessment according to activity (mining or mining-related), mining phase (construction, operational and decommissioning), and environmental component.

Secondly, an Environmental Management Programme (EMP) proposed for the expected impacts is also provided in the EIAMAP. This section of the EIAMAP includes proposed mitigation measures, time frames for implementation of the proposed mitigation measures and relative financial provisioning for the implementation of the proposed mitigation measure. These aspects comply with applicable legislation, as described in detail below.

4.10.1 Impact assessment methodology

Section 31(2)(k), Chapter 3 of the R. 543 (2010) in terms of the NEMA[2], 1998 requires an assessment of the extent, duration, probability and significance of the identified potential environmental impacts of the proposed mining operation. In order to comply with best practice principles, the evaluation of impacts was conducted in terms of the criteria presented in **Table 1.1**.

The significance of the current impacts, which exist even with mitigation measures in place, was determined using the methodology indicated below.

Table 1.1: Impact assessment criteria

Status		
Positive	+	Impact will be beneficial to the environment (a benefit).
Negative	-	Impact will not be beneficial to the environment (a cost).
Neutral	0	Where a negative impact is offset by a positive impact, or mitigation measures, to have no overall effect.
`Magnitude		
Minor	2	Negligible effects on biophysical or social functions / processes. Includes areas / environmental aspects which have already been altered significantly, and have little to no conservation importance (negligible sensitivity).
Low	4	Minimal effects on biophysical or social functions / processes. Includes areas / environmental aspects which have been largely modified, and / or have a low conservation importance (low sensitivity).
Moderate	6	Notable effects on biophysical or social functions / processes. Includes areas / environmental aspects which have already been moderately modified, and have a medium conservation importance (medium sensitivity).
High	8	Considerable effects on biophysical or social functions / processes. Includes areas / environmental aspects which have been slightly modified and have a high conservation importance (high sensitivity).
Very high	10	Severe effects on biophysical or social functions / processes. Includes areas / environmental aspects which have not previously been impacted upon and are pristine, thus of very high conservation importance (very high sensitivity).
Extent		
Site only	1	Effect limited to the site and its immediate surroundings.
Local	2	Effect limited to within 3-5 km of the site.

[1]EIAMAP: Environmental Impact Assessment and Management Action Plan.

[2] NEMA: National Environmental Management Act, 1998 (Act no: 107 of 1998).

Regional	3	Activity will have an impact on a regional scale.
National	4	Activity will have an impact on a national scale.
International	5	Activity will have an impact on an international scale.
Duration		
Immediate	1	Effect occurs periodically throughout the life of the activity.
Short term	2	Effect lasts for a period 0 to 5 years.
Medium term	3	Effect continues for a period between 5 and 15 years.
Long term	4	Effect will cease after the operational life of the activity either because of natural process or by human intervention.
Permanent	5	Where mitigation either by natural process or by human intervention will not occur in such a way or in such a time span that the impact can be considered transient.
Probability of occurrence		
Improbable	1	Less than 30% chance of occurrence.
Low	2	Between 30 and 50% chance of occurrence.
Medium	3	Between 50 and 70% chance of occurrence.
High	4	Greater than 70% chance of occurrence.
Definite	5	Will occur, or where applicable has occurred, regardless or in spite of any mitigation measures.

Once the impact criteria were ranked for each impact, the significance of the impacts was calculated using the following formula:

Significance = (Magnitude + Duration + Extent) x Probability

As is evident from the above equation, the extent (spatial scale), magnitude, duration (time scale) and the probability of occurrence of each identified impact were assigned a value according to the impact assessment criteria (presented in Table 1.1, above) and used to calculate the significance of each impact.

A Significance Rating was then calculated by multiplying the Severity Rating with the Probability, and is therefore a product of the probability and the severity of the impact. The maximum value that can be reached through the described impact evaluation process is 100 SP[3.] The scenarios for each environmental impact are rated as High (SP≥60), Moderate (SP 31-60) and Low (SP<30) significance as shown in **Table 1.2**.

Table 1.2: Definition of significance rating

Significance of predicted NEGATIVE impacts		
Low	0-30	Where the impact will have a relatively small effect on the environment and will require minimum or no mitigation.
Medium	31-60	Where the impact can have an influence on the environment and should be mitigated.
High	61-100	Where the impact will definitely influence the environment and must be mitigated, where possible.

[3]SP: Significant Points.

Significance of predicted POSITIVE impacts		
Low	0-30	Where the impact will have a relatively small positive effect on the environment.
Medium	31-60	Where the positive impact will counteract an existing negative impact and result in an overall neutral effect on the environment.
High	61-100	Where the positive impact will improve the environment relative to baseline conditions.

Once the significance rating of an impact before mitigation has been determined, the reversibility of the impact, ‘replaceability’ of the affected resources and the potential of the impact to be further mitigated also need to be determined. These factors are explained in the table below, and play an important role in the determination of the level and type of mitigation performed or to be implemented. **Table 1.3** sets out the criteria that were used to assess the reversibility, loss of resources and potential for further mitigation.

Table 1.3: Mitigation prediction criteria

Reversibility of impact		
Reversible	1	The impact on natural, cultural and / or social structures, functions and processes is totally reversible.
Partially	2	The impact on natural, cultural and / or social structures, functions and processes is partially reversible.
Irreversible	3	Where natural, cultural and / or social structures, functions or processes are altered to the extent that it will permanently cease, i.e. impact is irreversible.
Irreplaceable loss of resources		
Replaceable	1	The impact will not result in the irreplaceable loss of resources.
Partially	2	The Impact will result in a partially irreplaceable loss of resources.
Irreplaceable	3	The impact will result in the irreplaceable loss of resources.
Potential of impacts to be mitigated		
High	1	High potential to mitigate negative impacts to the level of insignificant effects, or to improve management to enhance positive impacts.
Medium	2	Potential to mitigate negative impacts. However, the implementation of mitigation measures may still not prevent some negative effects.
Low	3	Little or no mechanism exists to mitigate negative impacts.

The EIAMAP also provides a column in the table that identifies a specific impact as an I&AP[4] concern and also indicates who raised the concern as well as cross referencing with the relevant public participation parts of this document for more detail

The impacts expected to occur as result of the activities that are anticipated to take place at the proposed Project site may combine with those resulting from surrounding activities and land uses to form cumulative impacts, or to contribute to cumulative impacts that already exist. These have been assessed in a separate EIAMAP.

[4]I&AP: Interested and Affected Party/ies

4.10.2. Environmental Management Plan (EMP)

Regulation 33 of the EIA Regulations GN R.543 (2010) under the NEMA (1998) sets out the requirements for an EMP. To address these requirements, the EIAMAPs include the following aspects:

- **The mitigation management objectives and principles**– these have been identified to enable goals to be set for the environmental management of the proposed mining operations. Carefully planned management objectives and principles are the foundations of an effective EMP[5].
- Design plays a large role in the mitigation process, thereby ensuring that the project takes a proactive stance to environmental management. Therefore, **mitigation by design** has also been discussed where applicable in the EIAMAP's.
- **Proposed mitigation measures**– some mitigation measures / recommendations have been proposed that, when implemented, would enable the project to achieve the identified environmental management goals / objectives. The mitigation measures identified will modify, remedy, control or stop any action, activity or process that is identified as possibly impacting adversely on the environment.
- **Time Frames**–an indication of the estimated timeframe for the implementation of the proposed mitigation measures has been identified, where possible.

[5] EMP: Environmental Management Programme.

5. SURVEY RESULTS

5.1 Dominant soil types

Soil types within the Soil Study Area were mapped based on soil information gathered by means of random auger observations. The extent and location of soil types are shown on the soil map, Figure 3 which contains an abbreviated soil legend. A detailed soil legend for the **Soil Study Area** is provided in Table 2 in terms of the following aspects:

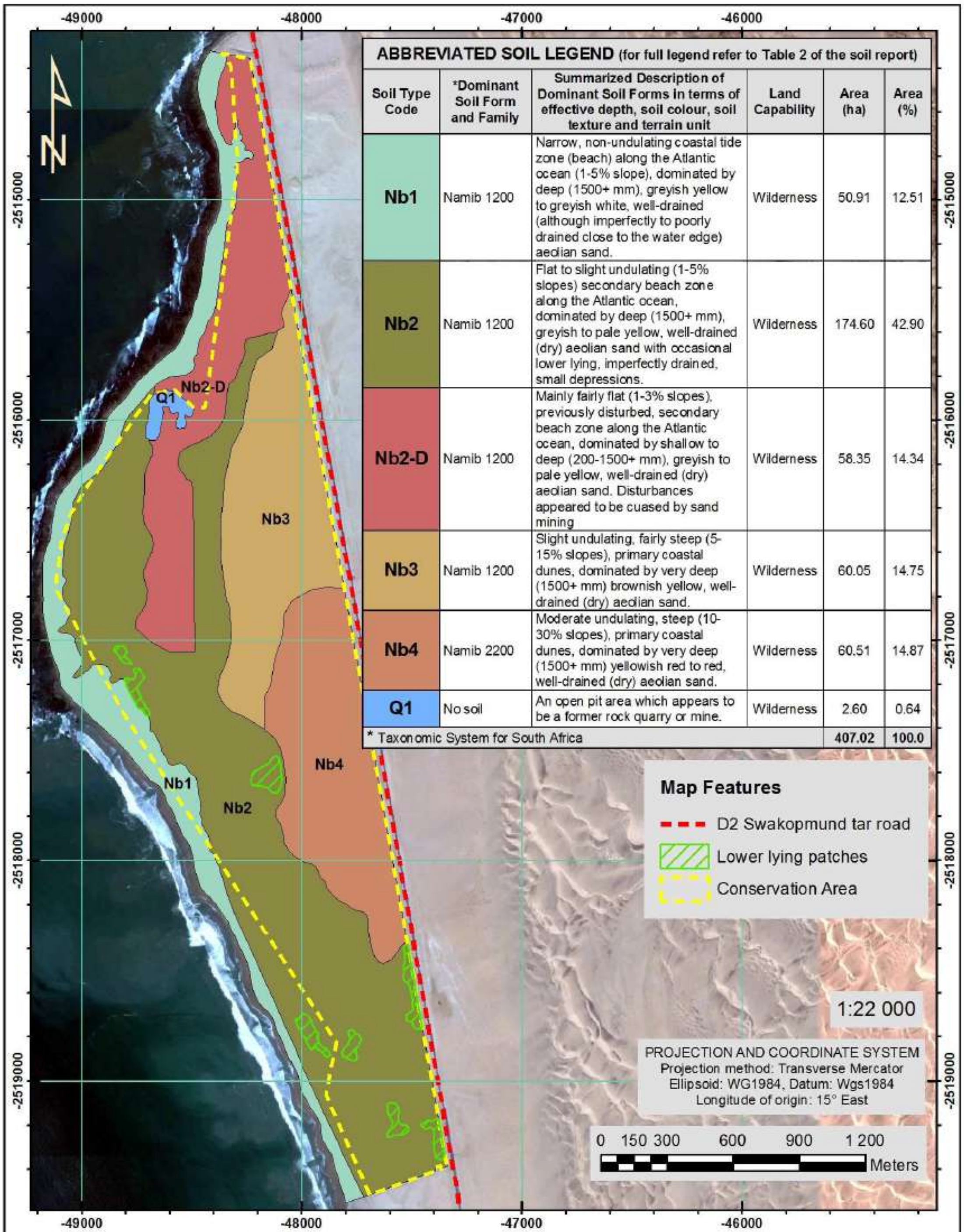
- Dominant soil forms and families and subdominant soil forms;
- The estimated clay content of the A and C-horizons;
- A broad description of the dominant soil form and terrain in terms of the effective soil depth, internal drainage, soil colour, soil texture class, terrain unit and average slope percentage range;
- A description of the soil horizon sequences;
- The derived erodibility class and dry land crop production potential;
- The land capability and wetland zone classification; and
- The area and percentage comprised by each soil type.

5.1.1 Soil types within the Soil Study Area

The soils within the Soil Study Area are largely homogeneous and consist of deep, aeolian sand of the Namib soil form. However, the topography differs slightly in 3 linear zones along the coastline and was differentiated as a coastal tide or primary beach zone, a secondary beach zone and a primary coastal dune zone (Figure 2). Although the dominant soil form within the 3 zones is the same, 5 soil types were differentiated based on topography and degree of disturbances and were symbolised as soil types Nb1, Nb2, Nb2-D, Nb3, Nb4 and Q.

Soil type Nb1 comprises the total primary beach or coastal tide zone. Soil types Nb2, Nb2-D and Q resides in the secondary beach zone and soil types Nb3 and Nb4 in the primary coastal dune zone. The location and extent of each soil type is shown in Figure 3 and is summarised in the soil legend Table 2.

Figure 3: Detailed soil map of the Soil Study Area



ABBREVIATED SOIL LEGEND (for full legend refer to Table 2 of the soil report)

Soil Type Code	*Dominant Soil Form and Family	Summarized Description of Dominant Soil Forms in terms of effective depth, soil colour, soil texture and terrain unit	Land Capability	Area (ha)	Area (%)
Nb1	Namib 1200	Narrow, non-undulating coastal tide zone (beach) along the Atlantic ocean (1-5% slope), dominated by deep (1500+ mm), greyish yellow to greyish white, well-drained (although imperfectly to poorly drained close to the water edge) aeolian sand.	Wilderness	50.91	12.51
Nb2	Namib 1200	Flat to slight undulating (1-5% slopes) secondary beach zone along the Atlantic ocean, dominated by deep (1500+ mm), greyish to pale yellow, well-drained (dry) aeolian sand with occasional lower lying, imperfectly drained, small depressions.	Wilderness	174.60	42.90
Nb2-D	Namib 1200	Mainly fairly flat (1-3% slopes), previously disturbed, secondary beach zone along the Atlantic ocean, dominated by shallow to deep (200-1500+ mm), greyish to pale yellow, well-drained (dry) aeolian sand. Disturbances appeared to be cuased by sand mining	Wilderness	58.35	14.34
Nb3	Namib 1200	Slight undulating, fairly steep (5-15% slopes), primary coastal dunes, dominated by very deep (1500+ mm) brownish yellow, well-drained (dry) aeolian sand.	Wilderness	60.05	14.75
Nb4	Namib 2200	Moderate undulating, steep (10-30% slopes), primary coastal dunes, dominated by very deep (1500+ mm) yellowish red to red, well-drained (dry) aeolian sand.	Wilderness	60.51	14.87
Q1	No soil	An open pit area which appears to be a former rock quarry or mine.	Wilderness	2.60	0.64
* Taxonomic System for South Africa				**407.02**	**100.0**

Figure 3: Soil map of the proposed Desert Rose Development area

Table 2: Detailed soil legend – Soil Study Area

SOIL LEGEND										
Soil Type Code	**Dominant Soil Form and Family**	**% Clay per horizon A, E, G, B**	**Summarized Description of Dominant Soil Forms in terms of effective depth, soil colour, soil texture and terrain unit**	**Description of soil horizon sequences of dominant soil forms**	**Erodibility**	**Dry land crop production potential**	**Land Capability**	**Wetland zone**	**Area (ha)**	**Area (%)**
Nb1	*Namib 1200	A: 1 C: 1	Narrow, non-undulating coastal tide zone (beach) along the Atlantic ocean (1-5% slope), dominated by deep (1500+ mm), greyish yellow to greyish white, well-drained (although imperfectly to poorly drained close to the water edge) aeolian sand.	Poorly developed, greyish yellow to greyish white, sandy Orthic A-horizons underlain by greyish yellow to greyish white Regic Sand C-horizons.	Moderate	None	Wilderness	Terrestrial	50.91	12.51
Nb2	*Namib 1200	A: 1-3 C: 1-3	Flat to slight undulating (1-5% slopes) secondary beach zone along the Atlantic ocean, dominated by deep (1500+ mm), greyish to pale yellow, well-drained (dry) aeolian sand with occasional lower lying, imperfectly drained, small depressions.	Poorly developed, greyish to pale yellow, sandy Orthic A-horizons underlain by greyish to pale yellow Regic Sand C-horizons.	High	None	Wilderness	Terrestrial	174.60	42.90
Nb2-D	*Namib 1200	A: 1-3 C: 1-3	Mainly fairly flat (1-3% slopes), previously disturbed, secondary beach zone along the Atlantic ocean, dominated by shallow to deep (200-1500+ mm), greyish to pale yellow, well-drained (dry) aeolian sand. Disturbances appeared to be cuased by sand mining	Poorly developed, greyish to pale yellow, sandy Orthic A-horizons underlain by greyish to pale yellow Regic Sand C-horizons underlain by bedrock.	High	None	Wilderness	Terrestrial	58.35	14.34
Nb3	*Namib 1200	A: 1-3 C: 1-3	Slight undulating, fairly steep (5-15% slopes), primary coastal dunes, dominated by very deep (1500+ mm) brownish yellow, well-drained (dry) aeolian sand.	Poorly developed, brownish yellow, sandy Orthic A-horizons underlain by brownish yellow Regic Sand C-horizons.	High	None	Wilderness	Terrestrial	60.05	14.75
Nb4	*Namib 2200	A: 1-3 C: 1-3	Moderate undulating, steep (10-30% slopes), primary coastal dunes, dominated by very deep (1500+ mm) yellowish red to red, well-drained (dry) aeolian sand.	Poorly developed, yellowish red, sandy Orthic A-horizons underlain by yellowish red to red Regic Sand C-horizons.	High	None	Wilderness	Terrestrial	60.51	14.87
Q1	No soil	-	An open pit area which appears to be a former rock quarry or mine.	No remaining aeolian sand.	High	None	Wilderness	Terrestrial	2.60	0.64
*** Dominant soil form and family**								**TOTAL**	**407.02**	**100.0**

Soil type **Nb1** represents the coastal tide or primary beach zone consisting of a narrow non-undulating zone adjacent to the water edge with short slope lengths and gradients of 1-5%. The western edge of this zone is saturated (along the ocean edge). The zone supports no vegetation and contains sporadic patches of sea shells and pebbles (Photo 1).

Photo 1: Coastal tide or primary beach zone (Soil type Nb1)

Soil type **Nb2** represents the southern portion of the secondary beach zone consisting of flat to slight undulating topography, isolated patches with miniature dune formation and dry lower lying patches or depressions as shown in Photo 2, 3 and 4 respectively. The flat to slight undulating and miniature dune sections support sparse desert vegetation but no vegetation occurs within the dry lower lying depressions.

Photo 2: Secondary beach zone – flat to slight undulating (Soil type Nb2)

Photo 3: Secondary beach zone – miniature dune formation (Soil type Nb2)

Photo 4: Secondary beach zone – dry lower lying patches or depressions (Soil type Nb2)

Soil type **Nb2-D** represents the previously disturbed northern section of the secondary beach zone as shown on Photo 5 (Google Earth). It appears if extensive sand harvesting took place to the west of the arrows in Photo 5. The sand was probably used to create a berm further north to serve as a barrier between the ocean and the D2 tar road. Some sand could have also been used for road and other building material.

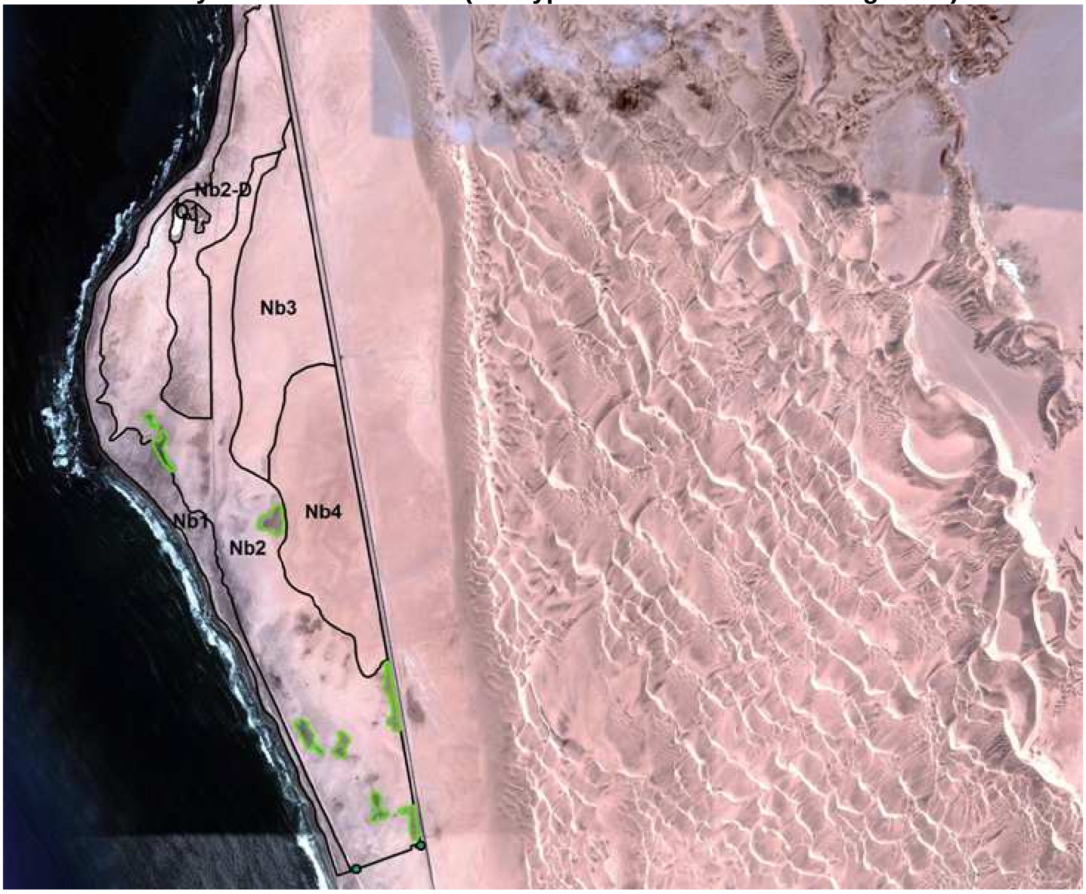
Photo 5: Disturbed northern section of secondary beach zone – (Soil type Nb2-D)

Soil type **Q** is an open pit area, also situated in the secondary beach zone with hardly any remaining sand as shown in photo 6. It could have been a former rock quarry or some minerals could have been mined. The majority of the pit floor is covered with water.

Photo 6: Open pit area in secondary beach zone – (Soil type Q)

Soil types Nb3 and Nb4 represent the primary coastal dune zone. These 2 soil types are dominated by the same soil form (Namib) but differ from each other in term of soil family (Namib 1200 and Namib 2200) as well as slightly in topography. Soil type Nb3 consists of slight undulating, brownish yellow dunes and soil type Nb4 of moderate undulating, yellowish red to red dunes as can be distinguish in Photo 7 (Goole Earth).

Photo 7: Primary coastal dunes zone (soil types Nb3 and Nb4 including other)



5.2 Land Capability

5.2.1 Land capability of the Soil Study Area

The total Soil Study Area was classified as wilderness land (Figure 4) due to the fact that it is too arid to sustain any plants of economic value. The area has no dry land crop production potential due to the low annual precipitation. The pure sandy texture of the soil subsequently provides a low quality growth medium. The area's uses rather lie in the fields of recreation and wildlife conservation.

Figure 4: Land capability map of the Soil Study Area

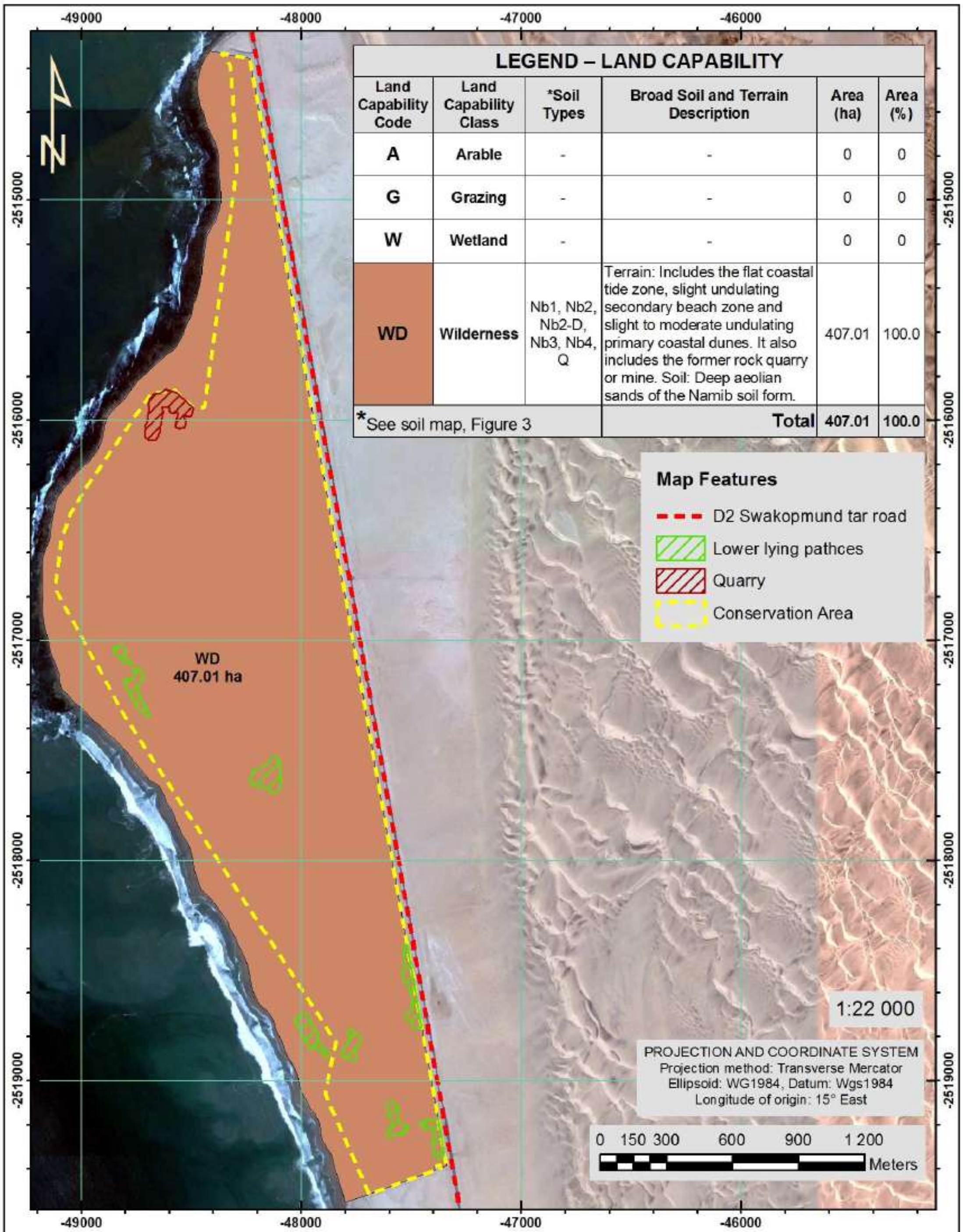


Figure 4: Land capability map of the proposed Desert Rose Development area

The land capability of the Soil Study Area is summarized in Table 3 which shows the soil types grouped into each land capability class, a broad description of the soil group, the number of units per land capability class, and the area and percentage comprised by each land capability class.

Table 3: Land capability classes – Soil Study Area

LEGEND – LAND CAPABILITY						
Land Capability Code	**Land Capability Class**	***Soil Types**	**Broad Soil and Terrain Description**	**Unit Count**	**Area (ha)**	**Area (%)**
A	**Arable**	-	-	0	0	0
G	**Grazing**	-	-	0	0	0
W	**Wetland**	-	-	0	0	0
WD	**Wilderness**	Nb1, Nb2, Nb2-D, Nb3, Nb4, Q	Terrain: Includes the flat coastal tide zone, slight undulating secondary beach zone and slight to moderate undulating primary coastal dunes. It also includes the former rock quarry or mine. Soil: Deep aeolian sands of the Namib soil form.	1	407.01	100.0
*See soil map, Figure 3			**Total**		**407.01**	**100.0**

5.3 Pre-mining land use

5.3.1 Land uses of the Soil Study Area

Only 3 land uses was observed during the time of the soil assessment as shown in Figure 5 and summarised in Table 4. The majority of the Soil study area (83%) is occupied by a Conservation Area which is fenced off with a cable fence to protect the breeding area of the Damara Tern. Neither the existence of the breeding area nor the status of any fauna and flora were assessed and should be done by specialists within those fields.

Figure 5: Pre-mining land use map of the Soil Study Area

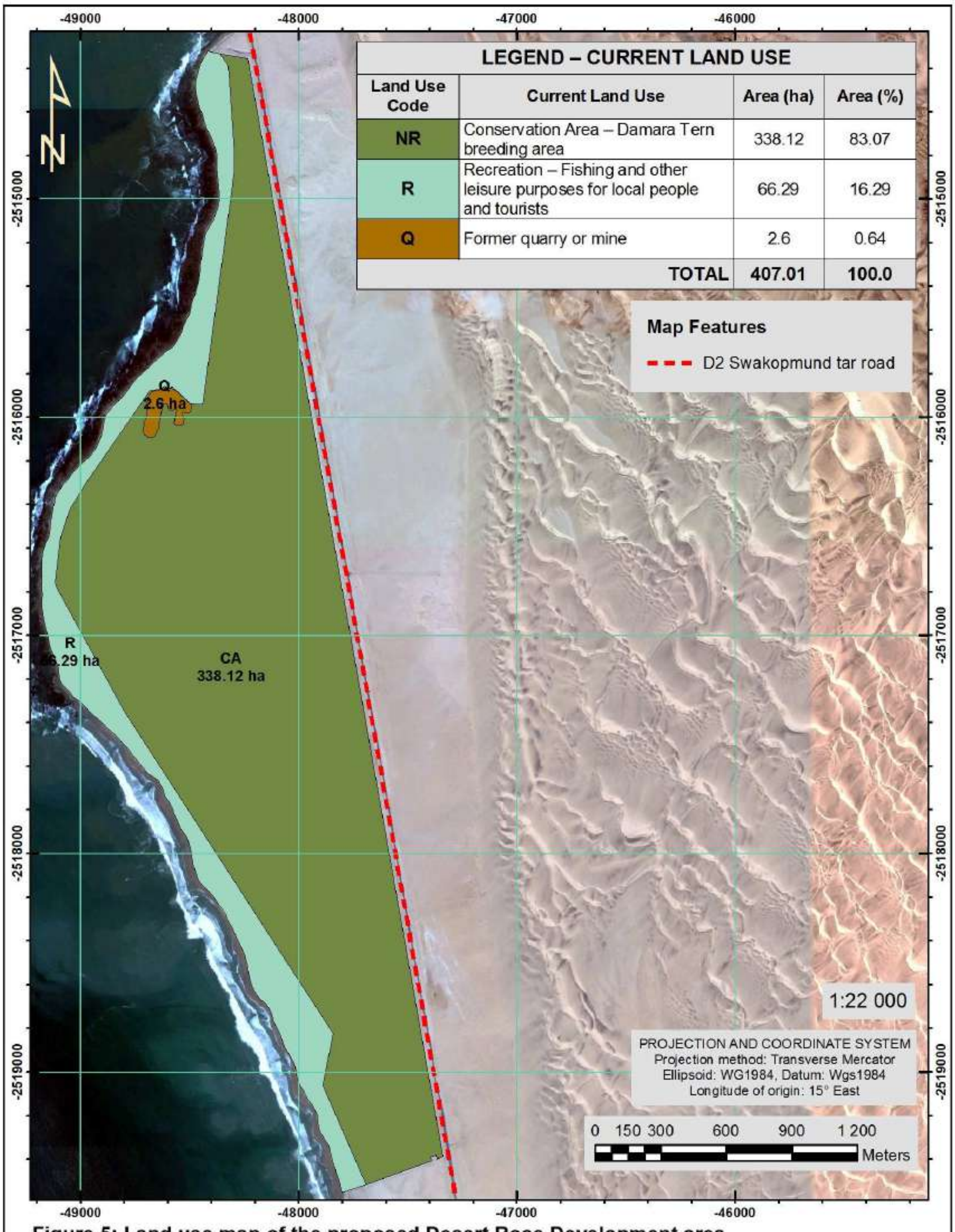


Figure 5: Land use map of the proposed Desert Rose Development area

The primary beach zone is utilized by local people and tourists for fishing and other leisure purposes.

No current activities were observed at the former quarry or mine and the area appeared abandoned.

Table 4: Current land uses – Soil Study Area

LEGEND – CURRENT LAND USE			
Land Use Code	**Current Land Use**	**Area (ha)**	**Area (%)**
NR	Conservation Area – Damara Tern breeding area	338.12	83.07
R	Recreation – Fishing and other leisure purposes for local people and tourists	66.29	16.29
Q	Former quarry or mine	2.6	0.64
	TOTAL	**407.01**	**100.0**

6. ENVIRONMENTAL IMPACT ASSESSMENT

The environmental impact assessment in terms of soils, land capability and land use for the proposed Development, including mitigation measures is compiled in a separate MS Excel spreadsheet.

7. CONCLUSION

Soils and land capability

The soils within the Soil Study Area are dominated by the Namib soil form, consisting mainly of deep Aeolian sand. Due to the severe arid climatic conditions and poor growth medium of the aeolian sand, no soil types within the Soil Study Area were classed as **arable**, **grazing** or **wetland** potential (Figures 3 and 4).

The total Soil Study Area was classed as **wilderness land** due to the fact that it is too arid to sustain any plants of economic value. The area barely support adapted desert type flora. The area has no dry land crop production potential due to the low annual precipitation and the pure sandy texture of the aeolian sand which subsequently provides a low quality growth medium. The area's uses rather lie in the fields of recreation and wildlife conservation which can include residential and business developments.

Considering the extreme low land capability of the soil resource, the impact of a land transformation from the current status to a residential development will be rendered very low. The long term economic value of such a development to Namibia will justify and by far exceed the economic value that could ever be generated via the soil resource.

Land use

Only 3 land uses was observed during the time of the soil assessment as shown in Figure 5 and summarised in Table 4 namely the conservation area, the former quarry or mine and leisure activities along the coastline.

The primary beach zone will not be occupied by structures of the development and the current recreation and leisure activities will not be adversely affected by the proposed development. The former quarry or mine area is abandoned and unproductive and has basically no land use that could be affected. However, if the residential development is erected across the breeding area of the Damara Tern, the breeding area will be destroyed.

8. RECOMMENDATIONS

The allege breeding area of the Damara Tern is the only factor that provides significant value to the proposed Development Area. The proposed Development Area consists more or less of 3 topographical zones and various habitat types was observed within each of the zones such as lower lying depressions, patches with miniature dune formation and slight to moderate undulating dunes. It is assumed that the Damara Tern will probably not breed all over the area but will prefer 1 or more of the existing habitats.

It is recommended that the exact extent and type of breeding habitat is studied and monitored by specialists during the breeding season. It might be possible to adapt the development plan to accommodate the breeding area. Furthermore, with a development of such a scale it will be possible to generate funds on a continuing basis to promote and support the conservation of other possible existing breeding areas.

REFERENCES

Chamber of Mines of South Africa, Coaltech Research Association, 2007. Guidelines for the rehabilitation of mined land. Johannesburg.

Department of Environmental Affairs and Tourism, 1998. Environmental impact management. Implementation of sections 21, 22 and 26 of the Environmental Conservation Act, 1989, Pretoria: Government Printer (1998).

Department of Water Affairs and Forestry, 2003. A practical field procedure for the identification and delineation of wetlands and riparian areas, DWAF, Pretoria.

Die Misstof vereniging van Suid Afrika, 1986. Bemestings handleiding, tweede hersiende uitgawe 1986, Pretoria.

Office of the Prime Minister, 2007. Promulgation of the Environmental Management Act, 2007 (Act No. 7 of 2007), 2007, Windhoek: Government Gazette of the Republic of Namibia (2007).

Soil Classification Working Group, 1991. Soil classification. A taxonomic system for South Africa. Institute for Soil, Climate and Water, Pretoria.

Van der Watt, H.v.H and Van Rooyen T. H, 1990. A glossary of soil science, Pretoria: Soil Science Society of South Africa (1990).

APPENDIX A
SOIL CLASSIFICATION SYSTEM

The classification system categorizes soil types in an upper soil Form level which is subdivided into a number of lower Family levels. Each soil Form (higher level) is defined by a unique vertical sequence of soil horizons with specific defined properties. The soil Families (lower level) are a subdivision of the soil Form (higher level), differentiated on the basis of specific characteristics such as leaching status, calcareousness, structure types and sizes etc.

In this way, standardised soil identification and communication is allowed by use of soil Form names and family numbers or names e.g. Hutton 2100 or Hutton Hayfield. The soil Form and soil Family together are referred to as soil types.

The soil Forms are indicated by the name and the Family by its appropriate number e.g. Hutton 2100. The soil Form and Family are then symbolized e.g. Hu and referred to as soil type Hu. The soil Form and Family are often further categorized based on effective soil depth, terrain unit and slope and a numerical number is added to the symbol e.g. Hu1. For example, where the Hutton 2100 soil Form and Family occurs at an effective depth of 900-1200 mm, it is symbolized and referred to as soil type Hu1, and where this soil Form and Family occurs at an effective depth of 600-900 mm it is symbolized and referred to as soil type Hu2.

APPENDIX B
SOIL PROPERTIES AND CHARACTERISTICS

Various terms in the soil legend are used to describe a series of soil properties and characteristics such as the dominant soil Form and Family, effective soil depth, internal drainage, and clay content per soil horizon and texture class.

1. Effective soil depth

Effective soil depth can be considered as the depth freely permeable to plant roots and water. Effective soil depth categories used in the soil legend are as follows:

Very shallow	< 300mm
Shallow	300-600 mm
Moderately deep	600-900 mm
Deep	900-1500 mm
Very deep	> 1500 mm

2. Internal drainage

Internal drainage is the flow of water (annual precipitation) through the soil profile. Soils with the ability to drain annual precipitation though the profile without waterlogged periods within certain parts of the profile are called **well-drained** soils. Soils which lack this ability will display properties indicating temporary to permanent water logged conditions in parts of the soil profile in the form of mottling, leaching or gleying.

Moderately well-drained soils mostly display impeded internal drainage in the lower profile e.g. soft plinthic horizons, which is the result of periodically fluctuating water tables which are characterized by mottling and accumulation of iron and manganese oxides.

Imperfectly drained soils mostly display impeded internal drainage in the upper and lower parts of the profile e.g. E and plinthic horizons, which is the result of periodic lateral flow of water in the profile and fluctuating water tables. Such soils are characterized by grey, leached, sandy horizons and mottled plinthic horizons.

Poorly drained soils mostly display impeded internal drainage in the upper and lower parts of the soil profile e.g. E, plinthic and G-horizons and are the result of long term to permanent wetness in the soil profile, which is characterized by grey, leached, sandy horizons, mottled plinthic horizons and gleyed clay horizons.

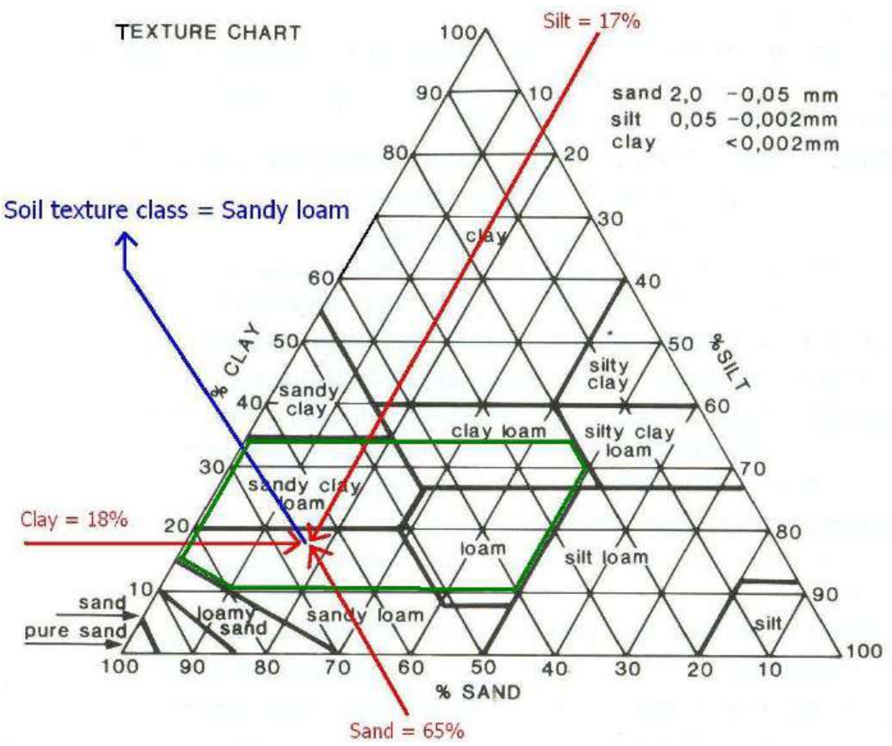
3. Texture class

Soil texture refers to the relative proportions of the various particle size separates in the soil. Particle sizes are defined in the following **fractions**.

Sand – (2.0 – 0.05 mm)
Silt – (0.05 – 0.002 mm)
Clay – (< 0.002 mm)

The relative proportions of these 3 fractions (as illustrated by the red arrows in Figure B1) determines 1 of 12 soil texture classes e.g. sandy loam, loam, sandy clay loam etc. The different texture class zones are demarcated by the thick black lines in the diagram. The green zone can be used as a guideline for moderate to high agricultural potential, but needs to be evaluated together with other soil properties.

Figure B1: Soil texture chart



APPENDIX C
WETLAND DELINEATION

1. Legal framework

In order to determine the existence and extent of a wetland in the proposed mining area the legal framework on what classifies as a wetland should be applied. The National Water Act, 1998 (Act 36 of 1998), (NWA), includes a wetland in the definition of a watercourse. A watercourse is:

- *"a river or spring;*
- *a natural channel in which water flows regularly or intermittently;*
- *a wetland, lake or dam into which, or from which, water flows, and*
- *any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse."*

A wetland is then further defined by the NWA as *"land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil".*

Based on the above definition, the Department of Water Affairs and Forestry (DWAF), now the Department of Water Affairs (DWA), published a set of guidelines describing field indicators and methods for determining whether an area is a wetland or riparian area, and for finding its boundaries (DWAF, 2005). These guidelines state that wetlands must have one or more of the following attributes:

- *Wetland (Hydromorphic) soils* that display characteristics resulting from prolonged saturation;
- The presence, at least occasionally, of *water loving plants (hydrophytes)*; and
- A *high water table* that results in saturation at or near the surface, leading to anaerobic conditions developing in the top 50cm of the soil.

Based on the NWA definition of a wetland, four indicators were identified within the DWAF (2005) guidelines to assist in identifying wetland areas:

- *Terrain Unit Indicator*. The topography of the area is usually used to determine where in the landscape the wetland is likely to occur.
- *Soil Form Indicator*. Certain soil forms, as defined by the Soil Classification Working Group (1991), are associated with prolonged and frequent saturation.
- *Soil Wetness Indicator*. The soil wetness indicator identifies the morphological "signatures" developed in the soil profile as a result of prolonged and frequent saturation.
- *Vegetation Indicator*. The vegetation indicator identifies hydrophilic vegetation associated with frequently saturated soils.

2. Processes in wetland soils and associated properties

The following processes normally take place under anaerobic/saturated or so-called wetland conditions:

- Mottling (localized colouring and alterations due to continued exposure to wetness);
- Concretions (accumulation and cohesion of minerals into hard fragments).
- Leaching (removal of soluble constituents by percolating water);
- Gleying (reduction of ferric oxides under anaerobic conditions resulting in grey, low chroma soil colours); and
- Illuviation of colloidal mater from one horizon to another, resulting in the development of grey sandy E-horizons and grey clay G-horizons.

These processes usually result in soil properties which provide undisputable evidence of temporary to permanent wetness such as:

Dark grey coloured A-horizons

The A-horizon is the upper 200-300 mm of the soil profile and is usually defined by a slightly darker colour due to a greater or lesser amount of humified organic matter. The dark grey A-horizon is common to almost all the soils found in permanent and seasonal zones. The dark grey colour usually appears only in the moist state and rapidly fades in to a plain grey colour when it dries out. The dark appearance is due to higher organic carbon content which builds up under the long term moist conditions in a wetland system. The carbon and also fine organic matter loses its dark colour in the dry state and the grey colour of the soil particles becomes prominent. The grey soil colour is the result of the removal of soluble constituents (iron oxides, silicate clay) by percolating water. The dark grey A-horizon is common in permanent, seasonal and temporary wetland zones.

Grey to pale grey E-horizons

The E-horizon underlies the A-horizon, having a lower content of colloidal matter (clay, sesquioxides, organic matter) usually reflected by a pale colour and a relative accumulation of quartz and/or other resistant minerals of sand or silt sizes. The E-horizon develops under high lateral flow (permanent or periodic) of water in the soil profile, which removes some colloidal matter to the lower soil profile and some further down the wetland system. The E-horizon is thus the flow path for shallow groundwater in the wetland zone. The grey and pale grey E-horizon is common in permanent and seasonal wetland zones and less common in temporary zones.

Yellowish grey E-horizons

The colour of the E-horizon reflects the intensity of removal of colloidal matter from the horizon. This results in the phenomenon that some E-horizons have a yellowish colour in the moist state but become grey in the dry state. The yellowish colour in the moist state is due to an incomplete covering of the mineral soil particle by ferric oxides and indicates a less leached state and less anaerobic (saturated conditions) conditions. The yellowish E-horizons are therefore strongly related to temporary wetland zones and occur less in seasonal or permanent wetland zones.

Plinthic horizons

Plinthic horizons are characterised by localization and accumulation of iron and manganese oxides under conditions of a fluctuating water table, resulting in distinct reddish brown, yellowish brown and/or black mottles, with or without hardening to form sesquioxide concretions. Plinthic horizons are the result of fluctuating water tables which implies wetter and dryer phases and are therefore found commonly in seasonal and temporary wetland zones and less in permanent wetland zones.

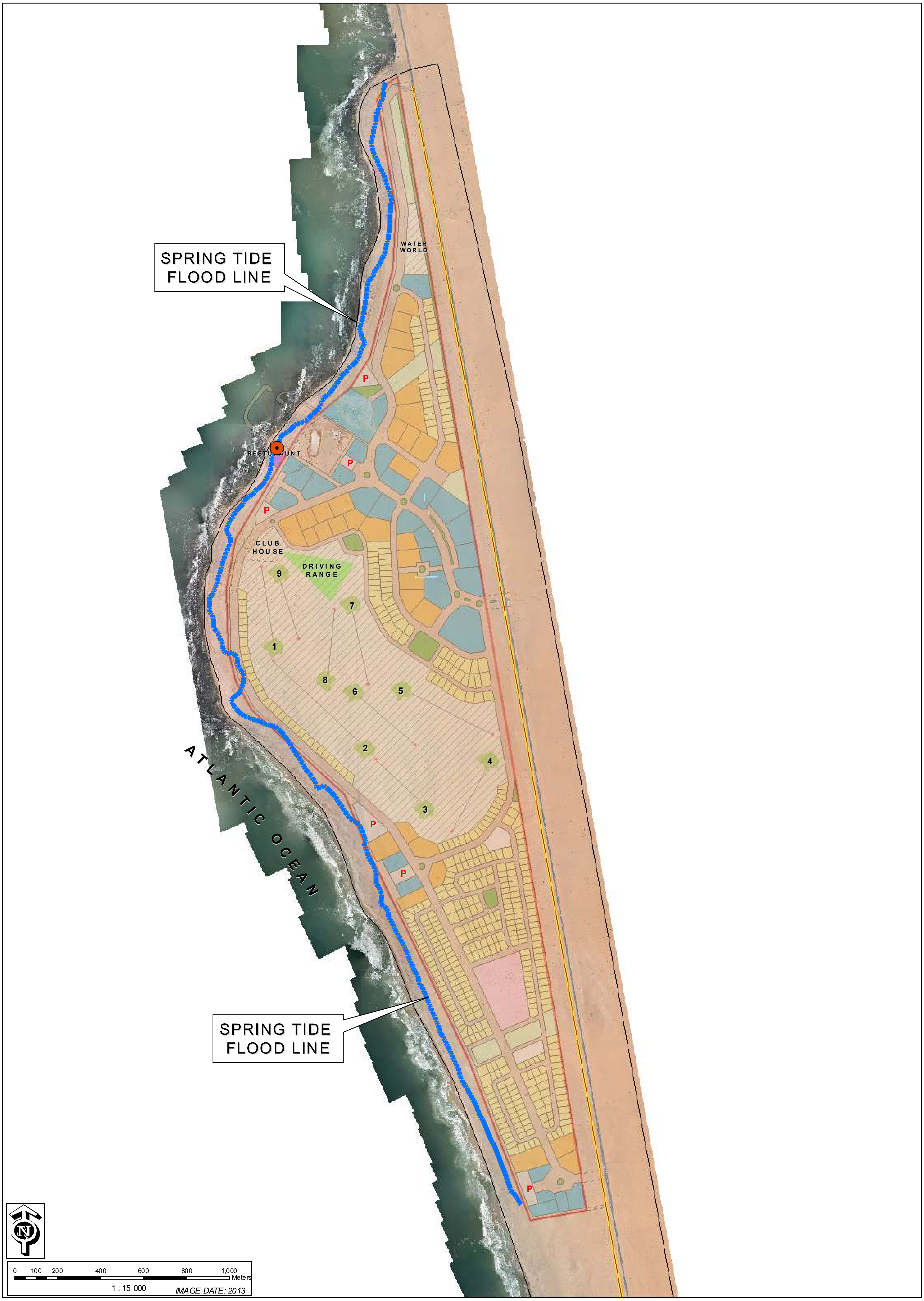
G-horizons

Gleying is the process of reduction of ferric oxides and hydrated oxides under anaerobic conditions, resulting in grey, low chroma matrix colours. This usually goes along with clay illuviation from the upper horizon which results in a grey clay horizon and is called a G-horizon. G-horizons are commonly found in permanent wetland zones, occasionally in seasonal zones and rarely in temporary wetland zones.

21.

APPENDIX R:

FLOOD LINE



SPRING TIDE FLOOD LINE
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RESTAURANT
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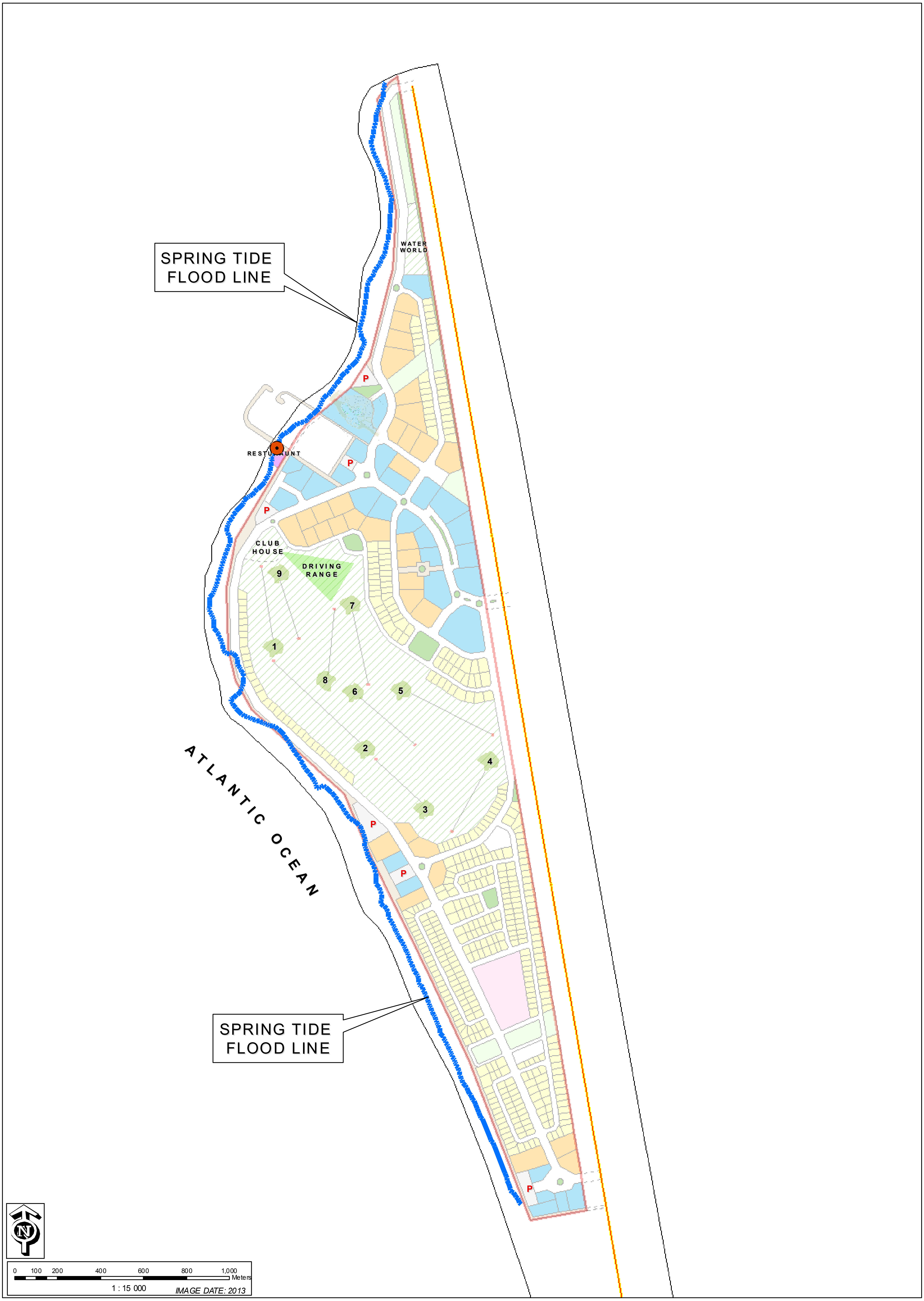
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DRIVING RANGE
ATLANTIC OCEAN
SPRING TIDE FLOOD LINE
0 100 200 400 600 800 1,000 Meters
1 : 15 000
IMAGE DATE: 2013

22.

APPENDIX S:

GROUND – SURFACE WATER IMPACT ASSESSMENT

global environmental solutions

Ground- and Surface Water Impact Assessment for the Namibia International Convention and Exhibition Centre

SLR Project No.: 733.14029.00001

Report No.: 2014-G-52

September 2014

Desert Rose Investments (Pty) Ltd
PO Box 2707
Walvis Bay

Ground- and Surface Water Impact Assessment for the Namibia International Convention and Exhibition Centre

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GROUND- AND SURFACE WATER IMPACT ASSESSMENT FOR THE NAMIBIA INTERNATIONAL CONVENTION AND EXHIBITION CENTRE

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ACRONYMS AND ABBREVIATIONS

Below a list of acronyms and abbreviations used in this report.

Acronyms / Abbreviations	**Definition**
VOC	Volatile organic compounds
mbgl	Meters below ground level
DWAF	Department of Water Affairs and Forestry

GROUND- AND SURFACE WATER IMPACT ASSESSMENT FOR THE NAMIBIA INTERNATIONAL CONVENTION AND EXHIBITION CENTRE

1 INTRODUCTION

SLR Environmental Consulting (Namibia) (Pty) Ltd was appointed by Desert Rose (Pty) Ltd to conduct a ground- and surface water impact assessment for the Namibia International Convention and Exhibition Centre and the associated urban development located about 8 km south of Swakopmund between on the B2 national road and the coast (Figure 1). The infrastructure will consist of (Windhoek Consulting Engineers (Pty) Ltd, 2013):

- Conference Centre and the associated hotels and restaurants;
- 9 hole golf course;
- Marina with associated breakwater structure;
- Business development centre consisting of office, retail and other business opportunities;
- General residential erven;
- Single residential erven;
- Public open spaces including seafront walkways, parks, etc.

2 GEOLOGICAL AND HYDROGEOLOGICAL BACKGROUND

The project area is underlain by surficial deposits (dune sand) of the Namib Desert, which in turn is underlain by metamorphic – and igneous rock types of the Damara Group Formations (Figure 1). Little information on the specific geology and hydrogeology that underlies the project area is available due to the absence of the borehole information in the area. Drilling and test pumping of boreholes at this stage was beyond the scope of the project.

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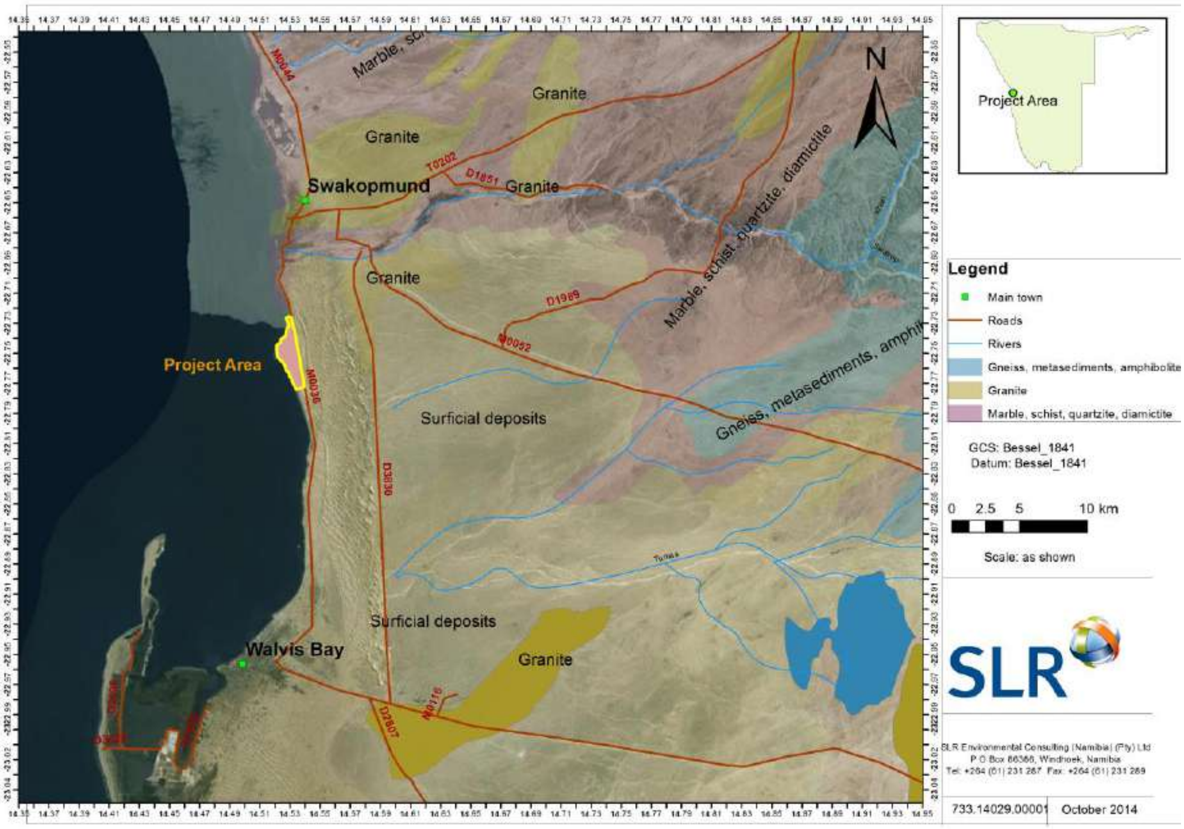

FIGURE 1: GEOLOGY

The information available at this stage is from the quarry that is present in the project area. It demonstrates fractured rock of metamorphic origin overlain by a thin soil cover consisting of dune sand. It also shows that the groundwater level is very shallow (1-2 mbgl), and that it is saline water. The hydrogeology can thus be summarised as a shallow, saline aquifer hosted in geological framework consisting of presumably fractured and weathered metamorphic rock types. The thin soil cover of dune sand which is absent in places, and the shallow groundwater table allows for easy infiltration of fluids from the surface, hence the aquifer can be classified as vulnerable to contaminating fluids from the surface. Groundwater recharge from rainfall is very little due to the low average rainfall of the area. The groundwater that is present in the area is due to the infiltration of seawater into the fractured bedrock.

3 REGULATORY FRAMEWORK

The context is which reference is made here to Namibian Law is to provide the framework according to which the impact assessment is conducted. For actual legal issues related a legal expert on the Namibian water law should be consulted.

3.1 THE 1956 WATER ACT

In 1956, the South African Parliament enacted the first comprehensive statute on water law in the form of the Water Act, 1956.

3.1.1 Applicability to South West Africa

The Water Act, 1956 remains operative and – apart perhaps from the Namibia Water Corporation Act, 1997 – the only substantive statute on water law in Namibia. The introduction of the Water Act, 1956 into the then territory of South West Africa was done in phases, and, due to the varying constitutional position and various legislative and administrative regimes, there is remaining uncertainty as to which provisions of the Water Act, 1956 are applicable in Namibia.

3.1.2 Relevance of the 1956 Act to the Namibia International Convention Centre

3.1.2.1 Effluents

Section 21 of the Water Act, 1956 deals with the requirements for purification of any waste water or any effluent or waste resulting from the use of water for industrial purposes, as well as the purification of sea water, is subject to the relevant requirements and standards set from time to time by government. A permit may be obtained for the exemption from these requirements where compliance is impractical in the particular purposes.

3.1.2.2 Pollution

Section 23 of the Water Act, 1956 criminalises any wilful or negligent act of polluting any public or private water, and there is a presumption that any act of pollution was wilful or negligent, until the contrary is proved.

3.1.2.3 Subterranean water

In terms of section 30 (1) of the Water Act, 1956, an owner of land is entitled to abstract or obtain any subterranean water for his own use for any purpose. However, in terms of section 30 (2), any such rights would be subject to regulations, such as the control over the drilling of boreholes, abstraction, etc. Furthermore, an owner who abstracts subterranean water may not without a permit sell, give or otherwise dispose of subterranean water to any person for use on any other land or convey such water beyond the boundaries of this land for his own use.

3.2 The Water Resources Management Act, 2004

In 2004, the Namibian Parliament adopted the Water Resources Management Act, 2004, which was published in the Government Gazette. In terms of section 138 of the Water Resources Management Act, 2004, that law would commence on a date to be determined by the Minister responsible for water by notice in the Gazette. Until date, no such gazette has been published and a further Water Resources Management Act, 2013 was published, and is stated to repeal the Water Resources Management Act, 2004. It follows that the Water Resources Management Act, 2004 is not in operation and that there is no duty on anyone to comply with its provisions.

3.3 THE WATER RESOURCES MANAGEMENT ACT, 2013

In 2013, the Namibian Parliament adopted the Water Resources Management Act, 2013, which was published in Government Gazette 5367 of 19th December 2013. In terms of section 134 of the Water Resources Management Act, 2013, that law is to commence on a date to be determined by the Minister responsible for water affairs by notice in the Gazette. It also repeals the Water Resources Management Act, 2004. Again, and until date, no such gazette has been published and it follows that the Water Resources Management Act, 2013 is not in operation and that there is no duty on anyone to comply with its provisions.

3.3.1 RELEVANCE OF WATER RESOURCES MANAGEMENT ACT OF 2013 TO THE NAMIBIA INTERNATIONAL CONVENTION CENTRE

3.3.1.1 Definitions

The following definitions have a bearing on this project:

- “Aquifer” means a water-bearing geological formation from which water can be abstracted;
- “Effluent” means liquid waste originating from domestic, industrial, agricultural or mining activities that has been treated in a waste water treatment facility and released into the environment in a dam, an evaporation pond, an aquifer, a river, the sea or onto the surface of the ground;
- “Pollute” in relation to water, means directly or indirectly to alter the physical, thermal, chemical, biological, or radioactive, properties of the water so as to render it less fit for any beneficial use for which it is or may reasonably be used or to cause a condition which is hazardous or potentially hazardous to -
  - (a) Public health;
  - (b) Animals, birds, fish or aquatic life or other organisms; or
  - (c) Plants;
- “Sustainable use” is relation to a water resource, means managing the use of water of the water resource in a way that it does not significantly reduce its long-term resource quality;
- “Wastage of water” includes unrecoverable loss of water due to leakage or the lack of maintenance of a waterwork or the misuse or undue consumption of water from a waterwork;
- “Waste”, includes sewage and any other matter of substance, wholly or partly solid, liquid or a gaseous state, which if added to water may cause water to be polluted;
- “Wastewater” means water containing waste;
- “Wastewater treatment facility” means a waterwork constructed or used for the containment, treatment, evaporation or storage of domestic, commercial, industrial, mining or agricultural effluent, including solid waste;
- “Water resource” means the whole or any part of a watercourse or an aquifer and includes sea meteoric water’

3.3.1.2 Water pollution control

Part 13 of the Water Resources Management Act, 2013:

- No water resources may be polluted. If pollution occurs, the effects must be remedied.
- Anyone who controls or supplies water is responsible for the wastewater under a licence to discharge effluent. From any area with domestic or industrial activities pollution must be prevented. No pollution of groundwater or surface water from agricultural land is allowed.
- A person may not allow any wastewater, effluent or waste to be discharged into a water resource/borehole/well or construct a treatment facility/disposal site polluting an aquifer. Wastewater from any obnoxious industries may not be discharged into the sewerage system except if there is an agreement.
- There is an exemption for certain discharges (upon application only), e.g. effluent from a private sewerage facility can be discharged into a water body or discharge which has been treated with alternative technologies.
- A licence application may require an EIA.
- Effluent discharges must be in compliance with quality standards
- A licence is valid for max. 5 years or as stated on licence.
- At least 3 months before expiry of licence an application for renewal can be submitted.

Water Resources Management Act of 2013 governs the quality of both fresh- and seawater resources. Ownership of water resources in Namibia below and above surface of the land belongs to the state.

3.4 OTHER APPLICABLE LEGISLATION

The context of referral to the Labour (Government Gazette of the Republic of Namibia, 2007) refers to the handling, storage and transport of hazardous substances. The Petroleum Products and Energy Act of, 1990 (Act no 13 of 1990) in the context of this project relates to the possible temporary storage of fuel products during the construction phase of the project, as well as bulk storage related to fuel stations for vehicles and motorised boats/yachts, heating/power generating facilities for the conference – and business centres.

4 BEST MANAGEMENT PRACTICES

Some best management practices for Water Conservation (APPENDIX A) and Marinas (APPENDIX B) have been provided. The purpose of providing these is to make the reader aware of some of the best management practices are available, and which should be considered when planning and developing the estate.

5 GROUNDWATER AS SEEN IN CONTEXT OF THIS PROJECT

5.1 A DESCRIPTION OF GROUNDWATER

Following is a brief description of what groundwater entails:

- Groundwater is the water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations;
- A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water;
- The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table;
- An aquifer is a layer of porous (primary or secondary porosity) substrate that contains and transmits groundwater;
- Polluted groundwater is less visible, but more difficult to clean up, than pollution of surface water. Groundwater pollution most often results from improper disposal of wastes on land. Major sources include industrial and household chemicals and garbage landfills, industrial waste lagoons, tailings and process wastewater from mines, oil field brine pits, leaking underground oil storage tanks and pipelines, sewage sludge and septic systems.

In this impact assessment the economic value of the groundwater for consumptive use, the economic value of groundwater for non-consumptive use is taken in consideration. It also considers the vulnerability to pollution or contamination, and its vulnerability to either or abstraction or discharge/recharge to the aquifer. This impact assessment also considers the impact on groundwater resources, such that is used for water supply, such as the Omdel Aquifer that is managed and operated by NamWater.

5.2 ECONOMIC VALUE FOR CONSUMPTIVE USE

The groundwater that underlies the site is saline due to the proximity of the ocean and on face value it seems unlikely that the saline aquifer will be targeted for groundwater abstraction for water supply purposes. However, it should be kept in mind that saline groundwater aquifers located nearby shorelines are viewed as potential resources for desalination water supply projects since costs savings are associated with pre-filtration of groundwater that contain less organic material compared than raw seawater. Saline groundwater is sometimes used in mining and industrial processes that does not require fresh water, aquaculture and brine production. Saline groundwater can be used for crop production, if blended to the correct salinity value.

With regard to aquaculture, some tilapia species can tolerate saline water up to 30,000 mg/l, and with regard to crop production white asparagus can be grown if the water is blended to 6,000 mg/l. As for industrial use, saline groundwater may be applied in the marina to washing and cleaning the berths and boats in order to save on fresh water consumption. It would be short sighted view to assume that the saline aquifer that underlies the project area does not have any economic value and would not be targeted for future abstraction.

5.3 ECONOMIC VALUE FOR NON-CONSUMPTIVE USE

The ecological importance of groundwater and its connection to other ecosystems are often overlooked, and more importantly the role that groundwater plays as an agent that transports pollutants from the source to downstream areas. Contaminants that enter the groundwater eco system as a result from the development can migrate to the shore line where it could impact aquatic- and bird life and human health.

5.4 VULNERABILITY TO CONTAMINATION

The aquifer is regarded as highly vulnerable to contamination due to the soil cover consisting of windblown dune sand that portrays a high infiltration capacity and the very shallow groundwater table. Therefore, protection of the underlying aquifer against groundwater contamination is an important consideration in this impact assessment.

5.5 VULNERABILITY TO ABSTRACTION AND/OR RECHARGE

This can be best assessed with hydraulic testing of boreholes to determine the potential groundwater source. However, since groundwater production on site is not a consideration of this project, the drilling and test pumping of boreholes was beyond the scope of this work. It is important to mention that aquifer recharge might come from irrigation of the golf course as well as landscape irrigation. Excessive irrigation practices might cause a rise of the already very shallow the groundwater table, with secondary impacts such as degradation of the soil on surface (become brackish), seepage/pooling of groundwater into the surface of low lying areas or the beach. Also linked to this is the surfacing of contaminants and fertilisers.

5.6 IMPACT ON GROUNDWATER RESOURCES USED FOR SUPPLY

We often hear that "water is our most precious resource", while at the coast, a desert environment, the Kuiseb – and Omaruru Delta aquifers that supplies groundwater are over utilised in order to meet the demand of the towns and the mines. The estimated demand of the Desert Rose Convention Centre Development is estimated at approximately $1Mm^3/a$ (Windhoek Consulting Engineers (Pty) Ltd, 2013), which amounts to approximately 20% of the rate that groundwater is pumped from the Omaruru Delta Aquifer in order to supply Henties Bay, Wotzkasbaken, Swakopmund, Arandis and some of the uranium mines. The rate of abstraction have been reduced recently after the incorporation of the Areva Desalination Plant in 2013, but it should be mentioned that the groundwater level in the Omdel Aquifer has declined in some areas with more than 20 meters as a result of over utilisation. Also, run-off from the Omaruru River that recharges the aquifer (via a groundwater recharge augmentation scheme) in the past 20 years has been less than predicted. Desalination of seawater has been implemented at the coast, and more desalinisation plants are foreseen in the future, but this is an expensive source of water. This impact assessment considers the impact on the groundwater supply sources as an important consideration in this impact assessment, with the recommendation of water conservation measures that could be introduced by the client.

6 SURFACE WATER AS SEEN IN THE CONTEXT OF THIS PROJECT

Natural on land surface water (excluding the sea) drainages are absent and will not be impacted by this project. Storm water however that is generated as a result of rainfall might be an agent to mobilise chemicals and toxins into the groundwater systems, the sea and the marina. Although the coastal area of Namibia has extremely low average rainfall, storm water must not be under estimated. Due to poor drainage provision the towns of Swakopmund and Walvis Bay floods even with minimal rainfall (Windhoek Consulting Engineers (Pty) Ltd, 2013). The Water Resources Management Act prohibits the discharge of any effluent (thus including storm water) into any water resource.

The sea is defined as surface water under the Water Resources Management Act. This impact assessment considers contamination as a result of the estate, including the marina and breakwater structure. It considers discharges of fuel products, storm water, chemicals, cleaners and sewage.

7 OVERVIEW OF CONTAMINANTS ON GROUNDWATER AND SURFACE WATER SYSTEMS IN THE FRAMEWORK OF THE PROJECT

7.1 HYDROCARBONS

Regardless of what type of petroleum product was released and the characteristics of the subsurface materials, a significant portion of the total release volume will not be recoverable by any existing remedial technology. Groundwater contamination by means of hydrocarbons is considered a serious incident and should be prevented by all reasonable measures possible. Hydrocarbon contamination related to this project are fuel products that are used during the construction phase of the estate, and above - or below ground storage tanks and reticulation systems for fuel stations and other facilities such as back-up generators, heating systems for the convention centre, fuel for kitchens, etc. Workshops where vehicles and machinery are serviced and washed are associated with the discharge of used oil and fuel products. The main risk to groundwater contamination is considered leak(s) that go undetected for long periods and/or accidental releases through spillage.

It is assumed that the marina will be equipped with a fuel dock. The release of fuel products into the marina due to accidental fuel and oil spills are not buffered as it may be the case of groundwater, and have a direct impact on the health of the aquatic life forms and eco systems, birdlife and human health. Any accidental release of hydrocarbons into marina and the sea is considered a serious incident.

7.2 SEWAGE

Sewage can lead to the contamination of groundwater by bacteria, nitrates, metals, trace quantities of toxic materials and salts. Sewage borne microorganisms include *E coli, Giardia,* Hepatitis, Cholera and Typhoid. The natural physical environment adds to the cleaning and purification of sewage water due to the natural physical, chemical and biological process such as oxidation, reduction, adsorption and precipitation. Isolated, small scale accidental releases of raw sewage or semi purified water is therefore not considered a major threat to the groundwater integrity and it is likely that the impact is reversible within a relative short period of time.

It is the unlimited long term release of sewage or semi purified water that is considered a serious source of groundwater contamination since the natural capacity of the physical and biological environment to break down the contaminants will be ultimately reached, with the contaminants spreading further. Since long term release/discharge adds water to the system, the process will be hydraulically assisted to spread the contaminants further in the aquifer. Continuous long term release will cause degradation of the aquifer.

Sewage treatment works will be constructed to purify the sewage water for water re-use application on the golf course. The capacity and type of the treatment works have not been indicated yet, but it was mentioned that trickle filter technology might be used. The annual average daily flow for sewage has been estimated at 2500m^3/day (≈900,000 m^3/a) (Windhoek Consulting Engineers (Pty) Ltd, 2013). The demand for the irrigation water for the golf course has been indicated to be 800 m^3/day (≈300,000 m^3/a). At this stage it has not been indicated what will be done with the surplus water coming from the sewage treatment plant.

Sewage released into the marinas from the yachts/boats can carry a health risk for humans coming into contact with the contaminated water. Sewage can also contaminate shellfish beds, and these contaminated shellfish can cause disease outbreaks in humans. Examples of these are Vibrio bacteria and the Norwalk virus. The decomposition process of sewage in marinas can lower the “Biological Oxygen Demand”, which can affect aquatic life and in severe cases kill fish.

7.3 IRRIGATION WATER

Landscape and agricultural irrigation is associated with fertiliser and pesticides. Pesticides decompose in soil and water, but the total decomposition time can range from days to years.

7.4 STORM WATER DRAINAGE

Contaminates picked-up by urban runoff that have the potential to adversely affect groundwater includes nutrients, salts, VOCs; pathogens, bromide and total organic carbon, pesticides and heavy metals including chromium, lead, nickel, and zinc (Pitt, Clark, & Field, 1999). The sources of these storm water toxicants comes from vehicle service areas, landscape area run-off and irrigation, parking area run-off, storage area run-off, street run-off.

7.5 MARINA

Surface (seawater) contamination of marinas is associated with fuel products (discussed), sewage and grey water from the boats (discussed), “maintenance waste” collected while maintaining boats included but not limited to machinery deposits, detergents/solvents, hydrocarbons, scraped paint, varnish, deck sweepings, wiping wastes, garbage, plastics, domestic solid waste. Similar to storm water run-off, this is a wide variety toxicants that can be detrimental to aquatic -, bird life and human health. It potentially can impact the water quality of the marina in terms of nutrient - and/or the oxygen levels if the marina does not have adequate circulation and flushing.

8 APPROACH AND METHODOLOGY

An assessment of the various environmental impacts that the project would have on surface- and groundwater, together with a severity ranking and mitigation measures are presented below, with ranking criteria as explained in Table 1 below.

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TABLE 1: CRITERIA FOR ASSESSING IMPACTS

Note: Both the criteria used to assess the impacts and the methods of determining the significance of the impacts are outlined in the following table. Part A provides the definition for determining impact consequence (combining severity, spatial scale and duration) and impact significance (the overall rating of the impact). Impact consequence and significance are determined from Part B and C. The interpretation of the impact significance is given in Part D.

PART A: DEFINITION AND CRITERIA*		
Definition of SIGNIFICANCE		**Significance = consequence x probability**
Definition of CONSEQUENCE		**Consequence is a function of severity, spatial extent and duration**
Criteria for ranking of the SEVERITY/NATURE of environmental impacts	**H**	Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action. Irreplaceable loss of resources.
	M	Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints. Noticeable loss of resources.
	L	Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints. Limited loss of resources.
	L+	Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	M+	Moderate improvement. Will be within or better than the recommended level. No observed reaction.
	H+	Substantial improvement. Will be within or better than the recommended level. Favourable publicity.
Criteria for ranking the DURATION of impacts	**L**	Quickly reversible. Less than the project life. Short term
	M	Reversible over time. Life of the project. Medium term
	H	Permanent. Beyond closure. Long term.
Criteria for ranking the SPATIAL SCALE of impacts	**L**	Localised - Within the site boundary.
	M	Fairly widespread – Beyond the site boundary. Local
	H	Widespread – Far beyond site boundary. Regional/ national

PART B: DETERMINING CONSEQUENCE					
				SEVERITY = L	
DURATION	Long term	**H**	**Medium**	**Medium**	**Medium**
	Medium term	**M**	**Low**	**Low**	**Medium**
	Short term	**L**	**Low**	**Low**	**Medium**
				SEVERITY = M	
DURATION	Long term	**H**	**Medium**	**High**	**High**
	Medium term	**M**	**Medium**	**Medium**	**High**
	Short term	**L**	**Low**	**Medium**	**Medium**
				SEVERITY = H	
DURATION	Long term	**H**	**High**	**High**	**High**
	Medium term	**M**	**Medium**	**Medium**	**High**
	Short term	**L**	**Medium**	**Medium**	**High**
			L	**M**	**H**
			Localised Within site boundary Site	Fairly widespread Beyond site boundary Local	Widespread Far beyond site boundary Regional/ national
				SPATIAL SCALE	

PART C: DETERMINING SIGNIFICANCE					
PROBABILITY (of exposure to impacts)	Definite/ Continuous	**H**	**Medium**	**Medium**	**High**
	Possible/ frequent	**M**	**Medium**	**Medium**	**High**
	Unlikely/ seldom	**L**	**Low**	**Low**	**Medium**
			L	**M**	**H**
				CONSEQUENCE	

PART D: INTERPRETATION OF SIGNIFICANCE	
Significance	**Decision guideline**
High	It would influence the decision regardless of any possible mitigation.
Medium	It should have an influence on the decision unless it is mitigated.
Low	It will not have an influence on the decision.

***H = high, M= medium and L= low and + denotes a positive impact.**

9 GROUNDWATER AND SURFACE WATER RISK ASSESSMENT

The potential ground- and surface water impact in the unmanaged scenario, management objective and mitigation actions are described under Table 2. Provided below is a summary of all the potential impacts listed and identified.

1. Groundwater contamination from chemicals used for general construction activities EXCEPT the handling and storage of fuel. The rating for consequence and significance is “medium” and “low” respectively for the unmanaged scenario, and low in the managed scenario;
2. Groundwater contamination from construction activities due to the spillage fuel or other hydrocarbon products. The rating for consequence and significance is “high” for the unmanaged scenario, and “low” in the managed scenario;
3. Groundwater contamination from sewage. The rating for consequence and significance is “medium” for the unmanaged scenario, and “low” in the managed scenario;
4. Impact on local aquifers due to the increased water demand. The rating for consequence and significance is “medium” for the unmanaged scenario, and “medium” in the managed scenario. SLR should note the assessment of this impact is not straightforward since (i) the water is supplied via water supply utilities to the estate and (ii) the water supply infrastructure planning at the coast involves the possible construction of more desalination schemes. Our assessment was done from the assumption that the additional desalination schemes will not realise in the near future, and in this framework, it is difficult to eliminate the impact entirely in the managed scenario. The impact will be reduced greatly if the client is serious regarding to the engagement of a water conservation program (SLR Namibia greatly emphasizes the importance on implementation of water conservation plan and – program);
5. Groundwater contamination coming from “water treatment plant sludge”. The rating for consequence and significance is “medium” for the unmanaged scenario, and low in the managed scenario;
6. Groundwater contamination from fuel station(s). The rating for consequence and significance is “high” for the unmanaged scenario, and “low” in the managed scenario;
7. Groundwater impacts from landscape - and golf course irrigation. The rating for consequence and significance is “medium” for the unmanaged scenario, and low in the managed scenario;
8. Surface water contamination from the Marina. The rating for consequence and significance is “high” for the unmanaged scenario, and “low” in the managed scenario.
9. Surface water and groundwater contamination from storm water drainage. The rating for consequence and significance is “medium” for the unmanaged scenario, and “low” in the managed scenario.

TABLE 2: GROUNDWATER – AND SURFACE WATER IMPACT ASSESSMENT AND MITIGATION MEASURES

Issue	Potential Groundwater Impact in the unmanaged scenario	Unmanaged assessment				Management Objective and Actions	Managed assessment			
		Sev	Sca	Dur	Pro	Mitigation	Sev	Sca	Dur	Pro
Groundwater contamination from chemicals used for general construction activities EXCEPT the handling and storage of fuel	**Severity and scale**. Relates to chemicals such as paint, sewage, battery acid, lubricants (oil/grease), cleaners, etc. Accidents that can potentially cause spillage to occur are considered small scale (i.e. in comparison to long term discharge such as undetected leak) and it is likely to be localized. Chemicals entering the groundwater systems however are considered a serious incident. The severity of the impact is considered medium and the scale localised. **Duration:** Impacts reversible and possible to rehabilitate with in the life of project. **Probability:** Considering the scale of the project accidental spillages are possible, and it considered possible that seepage can reach the groundwater table due the high infiltration capacity of the sand cover and the very shallow water table. **Consequence:** Medium **Significance:** Low	**M**	**L**	**L**	**L**	**Objective:** (i)To ensure that substances classified as hazardous are dealt with in a lawful manner (ii) that correct actions/procedures are taken when accidental spillages of chemicals occur. **Action plan:** (i) Compliance with the Labour Act (Government Gazette of the Republic of Namibia, 1992) that relates to the use, handling, storage and transport of hazardous substances. (ii) When construction commences, the contractor (s) should provide a schedule of all the chemicals that will be used on site for the purpose categorizing and identifying the need of any special arrangements that might be required to arrange for the a particular chemical/substance (iii) Developing of a “Groundwater protection plan for construction” that (a) lists actions to be taken in the event of emergency/spillage and which is in accordance to the law (d) provides a list of authorities to be contacted in the event of a spillage.	**L**	**L**	**L**	**L**

Issue	Potential Groundwater Impact in the unmanaged scenario	Unmanaged assessment				Management Objective and Actions	Managed assessment			
		Sev	Sca	Dur	Pro	Mitigation	Sev	Sca	Dur	Pro
Groundwater contamination from construction activities due to the spillage of fuel or other hydrocarbon products.	**Severity and scale**. Fuels or any other hydrocarbon product that reaches the groundwater are considered as incident with a high severity since it is difficult to reinstate the groundwater system to its original state. Accidents related to spillage are considered to have a localized impact. A major spill is regarded more than 200 litres (Goverment Notice: Ministry of Mines and Energy, 2000). **Duration:** Impact not reversible and long term. **Probability:** Considering the scale of the project accidental spillages are possible, and it considered possible that seepage from a major spill can reach the groundwater table due the high infiltration capacity of the sand cover and the very shallow water table. **Consequence:** High **Significance:** High	**H**	**L**	**H**	**M**	**Objective:** To accomplish spillage control for the storage and handling of fuel during construction. **Action plan:** (i) Application of "petroleum best practices" that relates to temporary storage and the handling of fuel products during construction.(ii) Compliance to Petroleum Products Act of 2000 (Government Notice: Ministry of Mines and Energy, 2000), (iii) Compliance to SABS standards regarding to the handling and storage of fuel products as published per Government Gazette (Government Gazette:, 2003) that relates to storage and handling of fuel products. (iv) On-site servicing and maintenance of construction vehicles must not be allowed.	**L**	**L**	**L**	**L**

Issue	Potential Groundwater Impact in the unmanaged scenario	Unmanaged assessment				Management Objective and Actions Mitigation	Managed assessment			
		Sev	Sca	Dur	Pro		Sev	Sca	Dur	Pro
Groundwater contamination from sewage	**Severity and scale:** Sewage treatment works will be constructed to purify the sewage water for water re-use application on the golf course. The capacity and type of the treatment works have not been indicated yet, but it was mentioned that trickle filter technology might be used. The annual average daily flow for sewage has been estimated at 2500m^3/day (≈900,000 m^3/a) (Windhoek Consulting Engineers (Pty) Ltd, 2013). Severity of sewage pollution coming as a result of a "once off" accidental release is considered low. The severity of long term leakage as a result of inadequate design and construction is considered medium, while impacts can be beyond the site boundary. **Duration:** Groundwater contamination coming from sewage will be reversible in the long term. **Probability:** Probable that in an illegal, inadequately designed/constructed scenario that long term release into the environment is possible. **Consequence:** Medium **Significance:** Medium	**M**	**M**	**M**	**M**	**Objective:** (i) To prevent sewage seeping into the groundwater system(s) though adequate design and construction to achieve 100% containment of the sewage effluent. **Action Plan:** (i) The Water Management Act (2013) with particular reference to effluent discharge standards must be complied with (Government Gazette, 2004) (ii) The design of the sewer system and the sewage treatment plant must be able to cope with peak flows. (iii) The design shall provide the facilities necessary to prevent discharge into storm water drains. (iv) If evaporation ponds are considered for the facility then, (a) it must be lined, (b) a leak detection system must be in place through the drilling of dedicated monitoring boreholes and (c) a groundwater monitoring plan must be considered	**L**	**L**	**L**	**L**

Issue	Potential Groundwater Impact in the unmanaged scenario	Unmanaged assessment				Management Objective and Actions	Managed assessment			
		Sev	Sca	Dur	Pro	Mitigation	Sev	Sca	Dur	Pro
Impact on the local aquifers due to the increased water demand.	**Severity and scale:** The engineering report (Windhoek Consulting Engineers (Pty) Ltd, 2013) indicated an Average Annual Daily Potable water demand of 2,950 m^3/day (about $1Mm^3$/a). This will add additional pressure on the groundwater resources (Omdel & Kuiseb) that supply the coastal towns if the additional demand is not planned for. **Duration:** Impacts due to the depletion on the groundwater resources are reversible over the life of the project. **Probability:** The aquifers will be impacted. In this sense it should be noted that the construction of more desalination plants, additional to the Areva Plant, are planned for future coastal water supply that might lower the probability. **Consequence:** Medium **Significance:** Medium (Note: It must be noted that an analysis of the sustainable abstraction, and the impact of increased abstraction falls beyond the scope of the work and has not been done in this study)	**M**	**M**	**M**	**M**	**Objective:** (i) To ensure the efficient use of groundwater resources. **Action Plan:** (i) Compilation of a water conservation program and the (ii) Implementation of best practices in water conservation in the planning, construction and operational phases (iii) A water balance of the entire system should be done (iv) Find uses/users/customers for the surplus water from the sewage treatment plant.	**M**	**L**	**L**	**L**

Issue	Potential Groundwater Impact in the unmanaged scenario	Unmanaged assessment				Management Objective and Actions Mitigation	Managed assessment			
		Sev	Sca	Dur	Pro		Sev	Sca	Dur	Pro
Groundwater contamination coming from “water treatment plant sludge”	**Severity and scale:** The method of sludge disposal or recirculation/re-use was not addressed in this stage of the project. The severity of groundwater contamination coming from sewage sludge that typically contains heavy metals and pathogens is considered medium. The spatial scale depends on where the sludge will be disposed. **Duration:** Groundwater contamination coming from the from sewage sludge are possible to be long term. **Probability:** If sewage sludge is incorrectly disposed of, then it is possible that groundwater contamination can occur. **Consequence:** Medium **Significance:** Medium	**M**	**L**	**M**	**M**	**Objective:** (i) To prevent groundwater contamination from sludge disposal **Action Plan:** (i) The sludge should not be allowed to accumulate or to be disposed on site. (ii). It should be removed to a landfill site with the correct certification for sewage sludge disposal.	**L**	**L**	**L**	**L**

Issue	Potential Groundwater Impact in the unmanaged scenario	Unmanaged assessment				Management Objective and Actions Mitigation	Managed assessment			
		Sev	Sca	Dur	Pro		Sev	Sca	Dur	Pro
Groundwater contamination from fuel station(s)	**Severity and scale**. The client has indicated the possibly of fuel stations for vehicles. It is also inferred that a fuel station will be constructed for the marina for the re-fuelling of yachts/motorised boats. Fuels or any other hydrocarbon product that reaches the groundwater is considered severe since it is difficult/impossible to reinstate the groundwater system to its original state. Accidental release relating to spillage is considered to have a localized impact. Long term releases due to leaking systems (i.e tanks, pipes, pumps) can have an impact beyond the site boundary. **Duration:** Impact not reversible and long term. **Probability:** In inadequately designed – and/or poorly managed scenarios the probability of accidental release term leakage is possible. **Consequence:** High **Significance:** High	H	M	H	M	**Objective:** (i) 100% containment of the product, (ii) to accomplish spillage control and (iii) to establish a leak detection system. **Action Plan:** (i) Compliance to Petroleum Products Act of 2000 (Government Notice: Ministry of Mines and Energy, 2000) and the SABS standards as published per government gazette (Government Gazette:, 2003) regarding the installation, handling and storage of fuel products and spillage control. (ii) Drilling and equipping of dedicated monitoring boreholes (iii) Regular sampling and testing for volatiles and hydrocarbon compounds for leak detection (iv) Application of "best practices in the petroleum industry" (v) Conduction of scheduled leak tests on the storage tanks and related infrastructure.	L	L	L	L

Issue	Potential Groundwater Impact in the unmanaged scenario	Unmanaged assessment				Management Objective and Actions Mitigation	Managed assessment			
		Sev	Sca	Dur	Pro		Sev	Sca	Dur	Pro
Groundwater impacts from landscape - and golf course irrigation	**Severity and scale**. The irrigation water for golf course will be around 800 m^3/day (≈300,000 m^3/a). Water not taken up in evapotranspiration and evaporative processes, will result in seepage that recharge to the shallow watertable. The impact can be twofold: (i) Groundwater contamination can occur from untreated pathogens, nutrients and salts – depending on the level of treatment and (ii) excessive irrigation might cause a rise in the water table to near surface with impacts related to soil degradation and seepage of groundwater into low lying depressions. The severity is considered medium, while the impact is considered reversible over the life of the project. **Duration:** Medium **Probability:** It's possible, with incorrect irrigation practices (too much irrigation). **Consequence:** Medium **Significance:** Medium	**M**	**L**	**M**	**L**	**Objective:** (i) Creating landscapes that are well designed and "water smart" from the start and (ii) to create and maintain water efficient irrigation. **Action Plan:** (i) The developing of estate rules for landscape design so that it is applicable to water scarce and desert environment (ii) compile and monitor landscape water budgets (iii) installation and maintain water efficient irrigation systems (iv) the application of a water conservation program. (v) drilling of dedicated monitoring boreholes that monitor the watertable and groundwater quality.	**L**	**L**	**L**	**L**

Issue	Potential Surface Water Impact in the unmanaged scenario	Unmanaged assessment				Management Objective and Actions Mitigation	Managed assessment			
		Sev	Sca	Dur	Pro		Sev	Sca	Dur	Pro
Surface water contamination from the Marina	**Severity and scale**. The Marina will have the potential to contaminate the sea with fuel coming from the fuel station, yachts/motorised boats, various kinds of soaps/detergents as result of washing of the boats, chemicals as a result of servicing and maintenance of the boats, disposal of domestic waste and (accidental) the release of sewage from the holding tanks of the boats. This severity is considered high since it might impact various kinds of marine - and bird life and human health. The scale is beyond the project boundary. **Duration:** If rectified, the situation is medium term and reversible. **Probability:** This kind of contamination is possible/frequent **Consequence:** High **Significance:** High	**H**	**M**	**M**	**M**	**Objective:** (i) 100% containment of fuel and fuel products from the fuel station (ii) prevention of the release of chemicals harmful to entire the environment (iii) prevention of the release of sewage into the marine environment (iv) to ensure that correct actions can be taken during an emergency related to chemical spillage. **Action Plan:** (i) Compliance with Namibian Water Resources Management Act of 2013 regarding to discharge of effluent (Government Gazette, 2004) (ii) Compliance with the Petroleum Products Act of 2000 regarding the storage and handling of fuel products (Government Notice: Ministry of Mines and Energy, 2000) and the sub regulations as published per government gazette (Government Gazette:, 2003). (iii) Application of best management practices for marinas that relates fuel management, facility cleaning and maintenance, boat maintenance, storm water practices, waste management, water efficiency, etc. (iv) The Marina must have a facility for the discharge of sewage from the boats, from where it is pumped to the sewage treatment plant. (v). A set of rules for boaters must be instituted that addresses all the issues related to contamination including boat repair activities, the in-water scraping of the boat hulls, and the washing of the boats (i.e. only environmental friendly and biodegradable cleaners must be used) (vi) An emergency plan must be developed that details the actions that must be taken in the case of an accidental release of fuel or chemicals and the clean-up procedures.	**L**	**L**	**L**	**L**

Issue	Potential Ground- and Surface Water Impact in the unmanaged scenario	Unmanaged assessment				Management Objective and Actions Mitigation	Managed assessment			
		Sev	Sca	Dur	Pro		Sev	Sca	Dur	Pro
Surface water and groundwater contamination from storm water drainage.	**Severity and scale**. The engineering report indicated (Windhoek Consulting Engineers (Pty) Ltd, 2013) the importance of the provision of proper storm water drainage. Storm water run-off has a high potential to contaminate groundwater and surface water resources. Storm water in urban areas is related to heavy metals, salts, pesticides, nutrients, and hydrocarbon compounds. The severity of storm water allowed entering into groundwater and surface water resources (such as at the Marina) are high, and while the scale is considered to be localised. **Duration:** Reversible over the life of the project – medium term. **Probability:** Possible with an adequately designed system **Consequence:** Medium **Significance:** Medium	**H**	**L**	**M**	**M**	**Objective:** To prevent storm water run-off to discharge onto surface- or groundwater environments. **Action Plan:** (i) Compliance to the Water Resources Management Act of 2013 with regard to the effluent discharge (ii) The storm water system must be adequate to handle peak flows. (iii) Under no circumstances should the storm water be allowed to discharge freely into land or marine environment(s). (iv) In the case of evaporation pond groundwater monitoring boreholes must be drilled for leak detection (v) the marina must be protected from surface water run-off.	**L**	**L**	**L**	**L**

10 CONCLUSIONS AND RECOMMENDATIONS

SLR Environmental Consulting (Namibia) (Pty) Ltd was appointed by Desert Rose Investments (Pty) Ltd to compile a ground- and surface water impact assessment for the planned Namibia International Convention and Exhibition Centre, about 8 km south of Swakopmund in a flat area between the B2 national road and the coast line. This study provided an overview of the regulatory framework and listed best management practices related to water conservation and Marinas. Ten possible impacts on ground- and surface water resources were identified that were addressed with mitigation measures as detailed in Table 2. In the mitigated scenario, all the impacts are rated as low, except for the impact of the increased demand on the local coastal aquifers. This impact however, assumes that additional desalination plants will not be constructed in the near future.

Conclusions drawn from this study are outlined as follows:

1. The project site underlain by a fractured saline aquifer that is vulnerable to contamination due to the high infiltration capacity of the overlying dune sand, and the shallow groundwater table;
2. The economic value for consumptive use are related to the possible use future desalination, aquaculture, brine production and the irrigation of crops tolerant to brackish/saline water;
3. The economic value for non-consumptive use relates to groundwater and its connection with other ecosystems. The role that groundwater plays as an agent that transports pollutants to other downstream areas should not be overlooked, and in this context the shoreline where it could impact aquatic – and bird life and human health;
4. From the impact assessment it was determined that issues with a low significance include groundwater contamination from chemicals used during construction activities EXCEPT the handling and storage of fuel;
5. From the impact assessment it was determined that issues with a medium significance include groundwater contamination from sewage, the impact on local groundwater resources due to the increased water demand, groundwater contamination coming from “water treatment plant sludge”, groundwater impacts due to landscape – and golf course irrigation, surface and groundwater contamination form storm water drainage;
6. From the impact assessment it was determined that issues with a high significance include groundwater contamination from construction activities related to fuel spillage and/or other hydrocarbon products, groundwater contamination from fuel stations, seawater contamination in the marina, sea - and groundwater contamination from storm water drainage;
7. A potential for surplus water from the sewage treatment plant exists, that will exceed the irrigation water demand for the golf course.

It is recommended that:

1. The mitigation measures detailed under Table 2 are implemented through the Environmental Management Plan;

2. Compliance to the Namibian Water Resources Act of 2013;
3. Compliance to the Petroleum Products Act of 1990;
4. Compliance to the Labour Act of 2007;
5. Monitoring boreholes for leak detection should be drilled at fuel stations; the sewage treatment plant and evaporations ponds (if any) ;
6. That the best practices for water conservation should be implemented as far as practically and financially possible, and provided that it is not contradictory with Namibian legislation;
7. That the best practices for Marinas should be implemented ,provided that it is not contradictory with Namibian legislation;
8. A water balance should be made for the entire estate, and additional "downstream" users/facilities for surplus purified irrigation water should be identified in order to minimise wastage of water, and to maximise the economic potential of water;
9. Water requirements of the estate that can make use of saline groundwater should be identified in order to safe on fresh water demand.

Braam van Wyk **Arnold Bittner**

(Report Author) **(Project Reviewer)**

REFERENCES

Colorado WaterWise. (2010, August). Guidebook of best practices for municipal water concervation in Colorado.

Government Gazette. (2013, Decemember 19). Promulgation of Water Resources Management Act, 2013 (Act No. 11 of the Parliament).

Government Gazette of the Republic of Namibia. (1992, July 31). Labour Act, 1992 regulations relating to the health and saftey of employees at work.

Government Gazette of the Republic of Namibia. (2007, December 31). Promulgation of Act of Parliament: No 11 of 2007: Labour Act, 2007.

Government Gazette:. (1979, June 25). Declaration of Certian Substances to be Group 1 - Hazardouz Substances. Namibia.

Government Gazette:. (2003, April). Ministry of Mines and Energy . *Petroleum and Products Energy Act. 1990: Application of certain standards under the petroleum products regulations*.

Government Notice: Ministry of Mines and Energy. (2000). Petroleum Products Regulations: Petroleum Products and Energy Act.

Pitt, R., Clark, S., & Field, R. (1999). Groundwater contamination from stormwater infiltration practices. *Urban Water*.

U.S Environmental Protection Agency . (February 2012). Best Management Practices for Marinas.

Wikipedia. (n.d.). *Groundwater*. Retrieved October 1994, from Wikipedia The Free Encyclopedia: http://en.wikipedia.org/wiki/Groundwater

Windhoek Consulting Engineers (Pty) Ltd. (2013). *Desert Rose Development: Engineering Services Report.*

APPENDIX A: BEST PRACTICES FOR WATER CONSERVATION

Water conservation measures are cost effective, due to the saving on the purchase of the water supplied, but also on reduced electricity costs on systems and appliances that utilises water. From a sustainability, - environmental and cost perspective(s) it is beneficial to be aware of the leading water saving practices that is applied elsewhere in the world. The paragraphs below highlight some of these practises that have been taken from the "Guidebook of best practices of municipal water conservation in Colorado" (Colorado WaterWise, 2010). Athough some of the practices highligthed here are withing the context of water utilities and municipalities, SLR still want to bring these under the attention of the client to see what can be adopted into the context on this project. Also, some of the measures may be implemented on municipal and local govement level based on recommendations of the client. We recommend that the client to study this guidebook in greater detail than summerised in this report.

Integrated resources planning, goal setting and demand monitoring

Integrated resource planning is a comprehensive planning effort that incorporates water conservation programmes as another option to meeting future needs. It encompasses least-cost analyses of demand and supply options that compares supply-side and demand-side measures on level playing field and results in a water supply plan that keeps costs as low as possible while still meeting all the essential planning objectives. Although greater integrated water resource planning at the coast is done higher levels and involves government, NamWater, the municipalities and the respective basin management committees, considering the size of the development, we suggest that a water conservation plan should be developed for the development itself. The idea of the plan should is to have a systems approach to engineer a complete and holistic view of the entire water cycle of the development. Such a plan should take due cognisance of the availability of water resources and the cost of supply. It should take into account the entire water balance and identify any surplus water or discharges. In this regard it should be mentioned that if the water balance indicate that surplus water is discharged, alternatives should be explored for the re-use of water, or an additional customer should be searched for in order to maximise water use, maximise the economic potential of water and minimise water losses. Additional benefits of integrated resource planning include:

- Reduced expense of developing new water supplies;
- Reduced operating/maintenance expenses from new or expanded water supply projects;
- Reduced environmental impact form new or expanded water supply projects;
- Increased transparency in the planning process and more public involvement;
- Balanced planning approach.

Conservation coordinator

The appointment of a full time or part time conservation coordinator would be a good idea to manage all a number water conservation programs (as part of a/the integrated water resources plan) in order keep the water demand of the development as low as possible and in harmony with the desert environment that it is located in. A conservation coordinator is critical for a development this scale aiming to keep the water demand at a minimum. A “go to” person for conservation is essential for the successful implementation and management of water conservation programs. The fundamental responsibilities of a water conservation coordinator are:

- Develop (or supervise development of) the utilities’ water conservation plan
- Organise and direct implementation of the conservation plan;
- Track, monitor and evaluate water conservation programs.

The conservation coordinator impacts the operations of the utility, improves customer understanding, assist in the development and dissemination of information, develops and supports conservation planning and program activities, and when necessary assists in implementing mandatory demand restrictions. Typical qualifications for a water conservation coordinator include the following:

- Principles and practices of public administration, particular municipal government;
- Public administration research methods, techniques and methods of report presentation;
- The organization of highly complex resource management programs;
- Water conservation laws, regulations, practices and techniques;
- Environmental planning;
- Landscape water efficient practices.

Metering, conservation oriented rates and tap fees, customer categorisation within the billing system

Impacts the way utilities charge new customers when they join the system, bill their existing customers for the water they use, and understand who the customers are and which customers might benefit from improved water efficiency. This category can also include advance metering systems that provide leak detection and real time use date for customers.

System water loss control

Water loss control is the practice of system auditing, loss tracking, infrastructure maintenance, leak detection and leak repair for water utilities. Leak detection and repair are familiar water agency practices, but true water loss control is more pragmatic than simply finding and fixing leaks. Auditing a water distribution for real and apparent losses and evaluating the costs of those losses is the foundation of water loss control.

The water audit typically traces the flow of water from the site of withdrawal or treatment through the water distribution system, and into customer properties. The water balance summarises the components and provides accountability, as all the water placed into a distribution system should – in theory – be equal all the water taken out of the distribution system. The combination of the system water audit and the water balance provide a variety of useful measures of the utility water loss. Water savings form water loss management programs depend entirely on the ongoing level of loss. It should be the goal of all water providers to limit real and apparent losses to economically efficient levels. Water losses vary significantly from system to system. Typically, systems with older pipes and /or higher pressure have greater real losses.

Water waste ordinance

A water waste ordinance is a local regulation that explicitly prohibits the waste of water and clarifies enforcement and penalties. Waste includes things such as irrigation run-off, irrigation that occurs on a prohibited day and/or time, leaks, use of inefficient fixtures and appliances, or the use of wasteful commercial or industrial processes. Water waste usually targets the excessive irrigation practices and drought restriction violations, but other sources of waste violations could also be levied such as excessive pavement washing, failure to repair leaks, etc. A water waste ordinance is usually enacted by the municipality or local government. The Desert Rose Convention Centre Development cannot enact a water waste ordinance. The owners of the development however should considering a set of guidelines that provides a definition what water waste entails, and that consider aspects as listed below:

- The amount of water that is reasonably necessary to establish and maintain a healthy landscape;
- Recommended hours for spray/sprinkle irrigation when losses to evaporation is minimal;
- Discourage watering landscape areas during periods of rain or high wind;
- Discourage applying water intended for irrigation to an impervious surface, such as a street, parking lot, alley, sidewalk or driveway;
- Encourage the use of a broom or mop to clean outdoor impervious surfaces such as sidewalks, driveways, patios, etc. instead of water, except when necessary for health and safety reasons or when other cleaning methods are impractical;
- Discourage water to pool or flow across the ground into any drainage way, such as gutters, alleys or storm drains;
- Encourage the immediate, as far as practically possible, repair of leaking or damaged irrigation components, service lines or other plumbing fixtures;
- Discourage the washing of vehicles with a hose, or at least a hose the lack an automatic shut-off valve;

Public information and education

Public information and education encompasses social marketing, school education, public outreach and education, and information campaigns aimed at raising awareness and fostering a culture of conservation and behaviour change. Central components of this best practice include effectively communicating the value of water, and delivering consistent and persistent messages. This best practice also includes measures to provide customers with timely information on their water consumption and alerts if unusual usage or leakage is detected. Conservation outreach programs helps to establish a culture of wise water stewardship and over time results in behaviour change.

Landscape water budgets, information and customer feedback

Landscape water budgets address landscape water use and encourage efficiency. Compared actual metered consumption against legitimate outdoor water needs of the customer based on landscape area, plant materials, and climate conditions. The customer is provided powerful information about the irrigation practices and efficiency at the property. Efficient irrigation practices have the capability of reducing landscapes water by up 35% in some cases.

Rules and regulations for landscape design

This best practise supports water efficient landscaping design, installation and maintenance practices. Creating rules for landscaping and irrigation system design is a relatively inexpensive method way to affect landscape water use. Proper installation and maintenance are needed to create and maintain water efficient irrigation.

Water efficient design, installation and maintenance practises for new and existing landscapes

Design, installation and maintenance of landscapes and irrigation systems can greatly impact water use. This best practise encourages water saving through water budgeting and proper design, installation and maintenance of existing and new landscapes and irrigation systems. The savings potential of a landscape designed, installed and maintained for water efficiency versus standard can be a 35% reduction in annual irrigation water use.

Irrigation efficiency evaluations

The efficiency of an irrigation system can greatly impact the amount of water that is used on a landscape. Over time even a well-designed and properly installed irrigation system becomes less efficient unless it is well maintained and operated at maximum efficiency. This best practice describes key considerations for maximising water efficiency through the use of regular efficiency evaluations. If the recommendations are implemented, the savings can range from 5 – 40%.

Rules for new construction

Water conservation measures that are “build in” to new buildings can help to slow the growth of new water demands. This best practise describes water efficiency specifications that some water utilities can make voluntary or mandatory for new residential development within their service area. High efficiency homes use approximately 15-30% less indoors than the standard new homes.

High efficiency fixture and appliance replacement for the residential sector

The goal of this best practice is to increase the rate of installation of high efficiency fixtures and appliances and to remove inefficient wasteful devices from service in favour of efficient products. Such fixtures and appliances include toilets, showerheads, washing machines, dishwashers. Various means are used to spur customers into replacing products.

Residential water surveys and evaluations, targeted at high demand customers

Water surveys and evaluations (frequently referred to as water audits) that identifies water savings opportunities and educate customers are a fundamental component of residential water conservation programs. Although often referred to all customers, high volume customers should be targeted first to maximise water savings and minimize program expenses. Surveys themselves don’t save water, but they often spur savings. Eliminating inefficient water use should be able to reduce annual consumption by 10-20% after implementing recommendations of a carefully conducted site audit.

APPENDIX B: BEST PRACTICES FOR MARINAS

Prohibition of the release of harmful substances into the sea is covered under the Water Resources Management Act of 2004. In a poorly managed scenario, marinas can be source of severe contamination due to direct contact with surface water (the sea), i.e fuel or oil spills that occur due the service and maintenance of boats or the accidental release of sewage from the holding tanks of boats/yachts. For this reason the most important best practices for marinas that were considered in this assessment (U.S Environmental Protection Agency , February 2012) are listed below. It is recommended that the client have a detailed assessment done regarding to the best management practices for marinas.

Fuel station operation

- Locate the fuel docks in a protected area to reduce the potential for accidents due to passing boat traffic;
- Design the fuel dock so that so that spill containment can be easily deployed so surround a spill ;
- Store spill containment and control materials in clearly marked and easily accessible location, attached or adjacent to the fuel dock;
- Keep oil absorbent pads and pillows available at the fuel dock for staff and customers to mop up drips and spills;
- Provide a stable platform for fuelling watercraft;
- Routinely inspect and repair fuel transfer equipment, such as hoses and pipes;
- Place plastic or non-ferrous drip trays lined with oil absorbent materials beneath fuel connections;
- Train the fuel dock personnel to handle and dispense the fuel properly. Fuel dock staff should be trained to (1) fill tanks slowly and carefully (2) prevent overfilling of fuel tanks by listening or keeping a hand on the air vent (3) remember that fuel expands in warm weather and leave at least 5% space in a fuel tank to allow for that expansion (4) attach a container or absorbent pad to the external vent fitting to collect overflow, as a precautionary measure (5) keep an absorbent pad or pillow ready to catch spills, drips and overflow (6) put a drip-pan under a portable fuel tanks. If possible fill portable fuel tanks ashore (7) prevent spills and respond to spills promptly if they do occur (8) give information and directions to customers.

Facility cleaning and maintenance

- Use cleaning products which may have less of an impact on the environment because they are less toxic and contain lower concentrations of volatile organic compounds (VOCs), ozone depleting chemicals (ODCs), and/or carcinogens;

- Avoid or minimize the use of any ammoniated, petroleum or chlorinated solvent-based cleaning agents.

Boat maintenance

- Avoid in-water bottom cleaning or hull scraping or any process that occurs underwater to remove antifouling paint from the boat hull. While this is a popular practice for racing sailboats prior to a race to reduce drag, it makes it impossible to capture and treat what's cleaned from the boat bottom.
- Pressure wash waste water should not be discharged directly to surface waters *(Authors note: The Water Resources Management Act of 2004 of Namibia prohibits the discharge of effluent into any water resource – Section 56).* To the extent possible, marina facilities should try to collect the wash water, treat it and either disposes of it at a sewage treatment plant. Where feasible, wastewater from the washing operation may be collected and reused through a closed loop pressure wash treatment system
- Minimize the amount of pressurized water used when boats are power washed.

Storm water non-structural practices (this applies if and when the developers considers a boat yard for boat repair and maintenance)

- Perform as much boat repair and maintenance as practicable inside work buildings;
- Where an inside workspace is not available, perform abrasive blasting and sanding within spray booths or tarp enclosures;
- Where buildings or enclosed areas are not available, provide clearly designated land areas as far from the water's edge as possible for debris-producing maintenance. Collect as much maintenance debris on tarps, filter fabric, or paved surface;
- Use vacuum sanders to collect dust and chips while removing paint from hulls;
- Establish a list of "yard rules" that do-it-yourselfers and contractors must follow when performing debris-producing boat maintenance;
- Clean hull maintenance areas immediately after any maintenance is done to remove debris, and dispose of collected material properly.
- Capture pollutants out of runoff water with permeable tarps, screens, and filter cloths;
- Store all potential pollutants such as pesticides, used oil containers, detergents, etc. under cover.

Storm water structural best management practices

Over land or via storm sewer systems, polluted runoff is discharged, often untreated, directly into local water bodies. When left uncontrolled, this water pollution can result in the destruction of fish, wildlife, and aquatic life habitats, a loss in aesthetic value, and threats to public health due to contaminated food, drinking water supplies, and recreational waterways *(Authors note: The Water Resources*

Management Act of 2004 of Namibia prohibits the discharge of effluent, which includes storm water, into any water resource – Section 56). Some suggested measures for marinas include the following:

- Plant a vegetated filter strip or buffer between impervious areas and the marina basin. A vegetated filter strip is a densely vegetated strip of land engineered to accept runoff from upstream development as overland sheet flow. Designed properly, a filter strip can provide a recreational amenity for your customers and enhance the appeal of your facility;
- Minimize impervious areas on the marina site by paving only where absolutely necessary. Use porous pavement for parking lots and lightly travelled access roads, or other penetrable materials such as gravel or crushed concrete;
- Direct roof runoff to drywells or position gutter down pipes so that they drain to vegetated areas. Avoid draining to concrete or asphalt;
- Use catch basins with deep sumps where stormwater flows to the marina basin in large pulses;
- Maintain catch basins regularly. Typical maintenance of catch basins includes trash removal if a screen or other debris-capturing device is used, and removal of sediment by a hired contractor or on-site wet-vacuum system. At a minimum, catch basins should be cleaned at the beginning and end of each boating season;
- Install oil/grit separators to capture pollutants in runoff. Water from parking lots and other areas likely to have hydrocarbons should be directed through oil/grit separators before entering any other management structure (Note: this practice requires a lot of maintenance);
- Add filters to storm drains that are located near work areas to screen solid materials out of runoff;
- Place absorbent materials in drain inlets to capture oil and grease.

Waste management

- Provide clearly marked, conveniently located recycling containers for customers and staff to use, particularly for plastic, glass and metal food/beverage containers and other recyclables generated at your facility;
- Do not put trash or recycling containers on docks, as waste can easily blow into the water;
- Encourage boaters to exchange excess paints, thinners, and varnishes rather than dispose. Provide a bulletin board where boaters can post notices if they have or need a particular substance, or establish a paint and maintenance chemical swap area for customers;
- Place covered trash receptacles in convenient locations away from the water for use by marina patrons;
- Prohibit disposal of fish waste in the marina basin. Post signs displaying the rules;
- Do not permit fish cleaning on docks and floats;

- Install a fish cleaning station at your marina;
- Clearly identify the fish cleaning stations with signs that list the rules and regulations for their use;
- Direct rinse water from fish cleaning areas to a sand filter or sanitary sewer. It should be free of solids;
- Encourage boaters to clean fish offshore where the fish are caught and discard of the fish in unrestricted waters, unless there are length limits for the type of fish caught.

Water efficiency

- Promote the a "water conservation" program at your facility;
- Fix leaks and drips;
- Equip all freshwater hoses with automatic shutoff nozzles;
- Water plants only when necessary. Indicators include wilting shrubs and grass that lies flat and shows footprints. Water in the cooler early morning or early evening to avoid stressing plants and to minimize water evaporation;
- Select plants suited to the existing conditions (i.e., soil, moisture, and sunlight) so that they will require little care in terms of water, fertilizer, and pesticides;
- Water deeply and infrequently rather than lightly and often. Deep watering promotes stronger root systems that enable plants to draw on subsurface water during hot spells and droughts;
- Cluster plants with similar water requirements. This practice will ease your maintenance burden, conserve water, and benefit the plants;
- Replace lawn areas with wildflowers, groundcover, shrubs, and trees;
- Direct downspouts into covered containers. Use the collected water on your landscaped areas.

Boater education

- Post signage in the boat yard describing environmentally preferable practices. Train employees about clean boating practices. Let them know what information is available to distribute to customers;
- Develop a series of fact sheets for boaters on topics such as petroleum control, vessel cleaning and maintenance, vessel sewage and waste management practices;

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23.

APPENDIX T:

ENGINEERING SERVICES REPORT

DESERT ROSE DEVELOPMENT

ENGINEERING SERVICES REPORT

SEPTEMBER 2013

Prepared by:

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PRELIMINARY INVESTIGATION INTO THE BULK SERVICES REQUIRED FOR THE DEVELOPMENT OF THE DESERT ROSE CONVENTION CENTRE DEVELOPMENT

1 INTRODUCTION

Windhoek Consulting Engineers have been appointment to do a preliminary investigation and cost estimate for the development of bulk services to the proposed site as well as internal services required for the development of the proposed new Desert Rose Conference centre and associated urban development.

The Desert Rose Conference Centre and Associated infrastructure will consist of the following:

- Conference Centre and associated hotels and restaurants;
- 9 hole golf course;
- Marina with associated break water structures;
- Business developments consisting of office, retail and other business opportunities;
- General Residential erven;
- Single residential erven;
- Public open spaces including sea front walkways, parks etc.

Due to the size of the development, special consideration was given to the provision of bulk services to the site to ensure a sustainable development. This was done through talks with all of the role players of which NamWater, Erongo RED, Swakopmund Town Council, Walvis Bay Town Council and the Roads Authority of Namibia was the most significant contributors.

Consideration was also given to ensure that the existing road users between the already congested road between Swakopmund and Walvis Bay is positive affected by the development, and that the environment is considered by ensuring responsible development and using “Green” Concepts such as renewable energy, and water purification.

The main focus of the report is the following:

- Listing all aspects of the development that was considered;
- Discussing the services requirements for the development;
- Investigating the available services in the area;
- Noting upgrading of existing services in the area to be able to provide the required service delivery;
- Indicating any challenges in providing the required services;
- Providing a preliminary cost estimate for the required services.

2 ROAD INFRASTRUCTURE

2.1 INTRODUCTION

A key aspect of any development is the consideration towards access to such development and the associated safety and level of services. Poor consideration to these aspects will result in a failed project and therefore forms an integral part of the investigation.

2.2 MAIN ACCESS TO DEVELOPMENT

Trunk Road 2/1 between Swakopmund and Walvis Bay is one of the busiest roads in Namibia second only to the road between Windhoek and Okahandja. A feasibility study has been completed in March 2013 that indicated that the proposed new road behind the dune belt should be constructed together with the upgrading of TR 2/1 to include passing lanes.

TR 2/1 will provide the main access to the development from both Swakopmund and Walvis Bay. The initial proposal will be to upgrade the section of the road to a duel carriage way that will improve road user level of service and safety. It is also proposed that three traffic circles (Roundabouts) be constructed at each of the three accesses to the site to promote traffic calming and safety at these points.

As the proposal of upgrading the road and the construction of traffic circles falls within the guidelines of the Roads Authority and the recently completed feasibility study, we do not foresee that access to the development will pose any challenges.

2.3 INTERNAL ROAD NETWORK

The internal road network consists of a combination of dual carriage ways within the business centre, and single carriage way roads that will service the residential erven and secondary business erven. The preliminary layout provides for maximum mobility within the business centre leading towards the marina and Conference Centre. Ample provision have been made for on-street parking within the business areas. Provision is also made for additional public parking in dedicated parking areas within the business centre.

Special consideration was also given for the provision of access to the sea-front along the length of the development. The public access is also complimented with public parking areas which is will increase public participation in the development.

The preliminary investigation did not indicate any implementation challenges. A preliminary design will however be done prior to the finalization of the township layout to ensure that there is sufficient space within all road servitudes to accommodate the envisaged structures.

2.4 PUBLIC WALKWAYS

A key feature of the development will be the integration of pedestrians and cyclists within the development. The key feature will be the construction of a walkway along the shore line along the development. A key feature of the walkway will be that it will be elevated and also act as protection for the road infrastructure during spring tide situations.

During the investigation, the Namibian Coast encountered one of the most severe spring tides that also coincided with heavy winds. During this period the sea entered the mainland to un-seen levels. This provided the ideal occasion to measure the extent of the sea-water ingress to determine the influence it will have on the proposed infrastructure. The survey indicated that there will be minimal ingress of sea water and the proposed structure will provide added protection.

2.5 ROAD INFRASTRUCTURE CONCLUSION

The proposed road infrastructure does not pose any challenges and the proposed upgrading of TR 2/1 and construction of internal roads and pedestrian walkways will ensure a pleasant experience when visiting the development.

The Development Cost of all roads, parking areas and public walkways is contained in Annexure A of this document.

3 STORMWATER INFRASTRUCTURE

The coastal area of Namibia has an extremely low average rainfall. Stormwater must however not be under estimated. Due to poor drainage provision, parts of the towns of Walvis Bay and Swakopmund floods even with minimal rainfall. The provision of proper stormwater drainage is therefore essential.

The majority of stormwater drainage will be accommodated with surface drainage. A subsurface stormwater drainage system will however be installed in the following areas:

- The Business centre;
- Area around the Convention Centre;
- Along the seafront road; and
- Any other area having a slope of less than 1% to accommodate surface drainage.

The development Cost of the stormwater infrastructure is contained in Annexure A of this document.

4 WATER SUPPLY

4.1 INTRODUCTION

Water is a scarce resource in Namibia. A desalination plant has already been developed to supplement the fresh water resource specifically for the supply to uranium mines within the area. Recently, NamWater has signed an agreement to secure potable water for future development in the Erongo Region

4.2 DISCUSSIONS WITH THE LOCAL & NATIONAL AUTHORITIES

The bulk potable water supply will have to be supplied from the NamWater Reservoirs situated to the east of Swakopmund, next to the B2 highway. This facility is currently being upgraded with the addition of a third reservoir. Although there is currently a 300mm diameter link between Swakopmund and Walvis Bay, next to the B2 coastal road, it will not be sufficient for the new proposed development. The line is also old and un-reliable. It could cater for temporary supply to the development during the construction phase. A dedicated new water main line will have to be constructed prior to the occupation of top structures in order to ensure water quantity and reliability.

The only challenge in the bulk water supply is the fact that the water will be provided from the Swakopmund reservoirs whilst the project area currently falls within the jurisdiction of the Walvis Bay Municipality. Discussions between the two local authorities and NamWater will have to be conducted, in order to determine which local authority claims ownership of the infrastructure, and on what terms.

4.3 POTABLE WATER

4.3.1 Water demand

The new proposed development consists of a variety of developable erven and a golf course as noted in the introduction. Table 4.1 below indicates the development zoning.

Table 4.1: Development Zoning

Zoning Description	Quantity
Single Residential	492
Multi / General Residential	32*
Business	34

*Taking the density zonings into consideration the 32 general residential erven equate to 1740 residential units.

The calculated estimated demands are as follows:

- Average Annual Daily Potable water demand: 2950 m^3/day
- Instantaneous Peak Demand: (Peak Factor : 4) 11 800 m^3/day
- Design Supply Demand for Supply main: 4 425 m^3/day

The design supply demand for the supply main is based on 1.5 times the Average Annual Daily Demand.

The golf course will be supplied with purified effluent. During the initial construction phase of the development, there will be little demand for potable water. There will also be little purified effluent for irrigation of the golf course. As the water demand increases (houses being occupied), the purified effluent available for irrigation will increase and the potable water demand for irrigation will de-crease. For the reasons stated above, no additional provision is made for potable water irrigation when the development is completed.

4.3.2 Bulk Water Distribution Network

The new development will have to be supplied by a dedicated supply main from the NamWater Reservoirs. This was discussed in preliminary meetings with NamWater. The route will start at the reservoirs, and then move along an approved route through the Swakopmund Townlands, cross the Swakopmund River and follow the B2 highway on the eastern side until it reaches the development. The pipeline will have an estimated length of 12 km.

Initial design considerations indicate a supply main of minimum Ø450mm for the demand indicated. The reservoirs are located at a height of 48m above mean sea level and the development's highest natural ground level being 26m. The available static pressure taking losses into consideration will be approximately 16.3m at this point with an Ø450mm supply main.

The development itself has a static pressure difference of approximate 22m and will result in an available pressure head of between 18m and 40m (35m taking minor losses into consideration).

Taking this into consideration it can be safely stated that certain parts of the development will have to be boosted on site in order to achieve the minimum required design static pressure of 24m. Pressure boosting will specifically be required on high lying ground with multi-story buildings as well as the proposed Convention Centre. During the detail design of the water infrastructure, local boosting can be investigated.

The estimated development Cost of the bulk water supply is contained in Annexure A of this document.

4.3.3 Internal Potable Water Distribution Network

The internal potable water network will consist of various diameter mains, sufficient to provide the required static pressure to the erven. As stated in section 4.3.2, boosting may be required in certain parts in order to achieve the minimum required static pressure of 24m.

The network will follow a dual network design methodology which do not require any erf connections to cross the internal roads and will consist mainly of uPVC Class 9 and HDPE Class 10 pipework ranging from 250 mm diameter down to 32 mm diameter.

The estimated development cost of the internal water supply is contained in Annexure A of this document.

4.3.4 Internal Fire Reticulation

The development is classified as a moderate risk group due to the type of developments in the epicentre of development near the convention centre location. The bulk potable water infrastructure will also serve as the infrastructure for the fire reticulation provision required.

Preliminary design indications show that on site storage will not be required for fire requirements, as the bulk reticulation network has the capacity to deliver the fire requirements as required by the design standards. This will have to be investigated further and confirmed.

The construction of fire hydrants is the only additional requirement. The estimated development cost of fire reticulation is contained in Annexure A of this document.

4.4 Irrigation Water

The irrigation infrastructure will mainly service the proposed golf course. According to Design Specialists the irrigation requirement for the golf course will be approximately

800m³/day. The semi-purified effluent generated by the treatment plant will be sufficient enough to service the golf course, and once the development is at full capacity there will be surplus treated effluent. This can be utilised as an irrigation service to the residents and parks. The irrigation system is considered as part of the golf course construction and is not considered in the engineering design report.

5 SEWER DRAINAGE AND TREATMENT

5.1 DISCUSSIONS WITH THE LOCAL AUTHORITIES

Detail discussion must still be done with the respective local authorities. These discussions normally take place once the project proceeds, in order to discuss the details and design considerations on the sewer infrastructure and treatment facilities.

5.2 DESIGN APPROACH

The design of the sewage infrastructure for this development recognizes and embraces the fact that water is a scarce and expensive commodity in Namibia. The whole development will be serviced with an enclosed gravity sewer network, which will convey the effluent to strategic placed pump stations. The pump stations in turn will convey the accumulated effluent to a Waste Water Treatment Plant. This plant will use technology capable of treating the effluent to the point of re-use for irrigation purposes. The bulk of the irrigation water will be used on the golf course.

Each component of the planned sewage infrastructure is discussed in more detail below.

5.3 SEWAGE DRAINAGE NETWORK

The topography of the site splits the development into three to four distinct catchment areas. Each of these catchment areas will be served by a sewage drainage network comprising a network of mostly 160 and 110mm diameter sewer lines. A small portion of the lines will be 200mm and 250mm diameter lines to compensate for heavy flows from the dense central area around the Convention Center.

A preliminary design done indicates that the sewage network will consist of approximately 24 km sewer lines, and 271 sewer manholes. Excavation will range between 0.8 m and 5.5 m.

5.4 DESIGN FLOW CALCULATION

Based on the guidelines sketched in the generally accepted "Red Book", effluent volumes for the full development are calculated as indicated in Table 5.1.

Table 5: Estimated Sewage Flows

Area	Estimated Flows
Number of Erven Served	492
Number of General Residential Units according to density	1740
Annual Average Daily Flow (DWF)	2500m³ per day
Annual Average Daily Flow (WWF)	2875m³ per day
Peak Factor	1,5
Peak Daily Flow	180m³ per hour

5.5 EFFLUENT TREATMENT AND RE-USE

The preliminary design considers the design and construction of Trickle Filter Plants to be the most appropriate technology for this development. These plants are provided as package units from specialist installers. These units can be phased in modules in order to reduce costs. For the purpose of this report a 500m³/day module was opted for as Phase 1. Additional 500m³/day units can be added as the development grows.

The design of these plants will be discussed with both the Local Authorities and the Department of Water Affairs who regulates the discharge of treated sewage effluent.

5.6 ESTIMATED CONSTRUCTION COST

The estimated construction cost for the sewage infrastructure required to serve this development is indicated in Annexure A of this document.

6 SOLID WASTE MANAGEMENT

The project area cannot cater for solid waste management. Solid waste will have to be collected by either the Swakopmund Town Council or Walvis Bay Town Council. As soon as the jurisdiction of the development has been finalized, the discussion with the local authority can start. The provision for solid waste will not have any significant impact on the development cost and will be part of the municipal monthly rates and taxes charged to the property owners.

7 ELECTRICAL INFRASTRUCTURE

7.1 ESTIMATED SUPPLY REQUIRED

A total electricity load of approximately **11MVA** is forecast for the Desert Rose Development as indicated below:

- Residential: 474 Stands Approx. 1.7 MVA
- General Residential: 1,704 Stands Approx. 6.0 MVA
- Business: 30 Stands Approx. 1.3 MVA
- Convention Centre: 1 Stand Approx. 2.0 MVA

Currently there is no formal contribution toward bulk electrical supply. The supply authority is however working on a policy for bulk electrical network contribution. Provision for the network contribution is made in the cost estimate contained in Annexure A of this document.

7.2 MEDIUM VOLTAGE SUPPLY

The development will be supplied directly from the NamPower Main Intake **Feld Switching Station** situated in Mandume Ya Ndemufayo Street approximately 4km from the development. It is projected that enough capacity is available at the intake station. A proposal to supply the development via 2 x 185mm^2 11kV XLPE underground cables is made.

A new Switching Station will be required at the development from where 3 x 11kV 70mm^2 rings will supply the residential and business areas and 2 x 11kV 70mm^2 cables will supply the Convention Centre.

7.3 DESERT ROSE MV, LV RETICULATION AND SERVICE CONNECTIONS

An underground electrical reticulation will supply 13 Substations in the development. Underground service connections will be via approximately and initially 90 electrical metering kiosks fed from the substations. The Electrical Reticulation is according to Erongo RED standards

7.4 STREET LIGHTING

Approximately 180 streetlights are planned for the main streets, while approximately 200 streetlights are planned for secondary roads. Streetlights are according to Erongo RED standards.

7.5 COST ESTIMATE

The estimated construction cost is indicated in Annexure A of this document.

8 MARINA AND ASSOCIATED BREAK WATER STRUCTURE

The development proposed the development of a marina and associated break water structure. The feasibility of these structures can only be confirmed with a preliminary design and modeling of the facility to determine the optimum shape and size. Depending on the outcome of the preliminary design and feasibility, a decision will be made regarding the construction thereof.

The preliminary cost estimate for the marina and associated break water is indicated in Annexure A of this document.

9 CONCLUSION

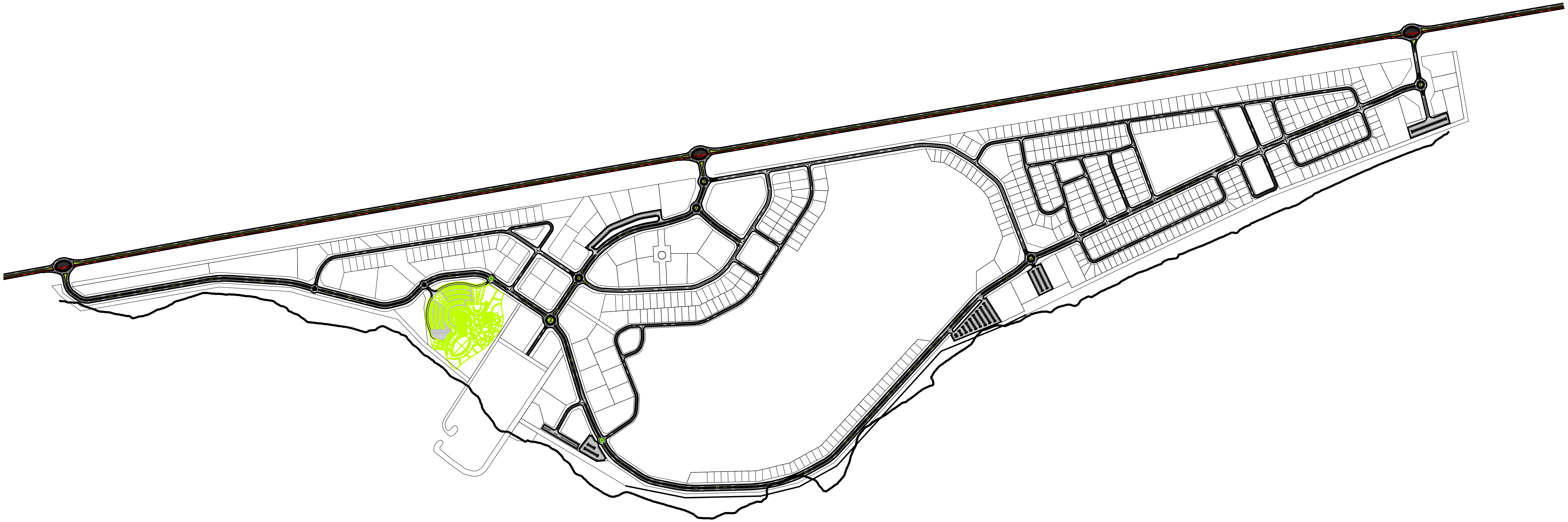
The Desert Rose development will significantly impact on the available municipal infrastructure available in the project area. From the initial investigation seriously limiting factors could be identified. It will however be very important to inform the local authorities on the progress of the project in order to afford them the opportunity to upgrade their infrastructure as required. Delay in communication could result in availability problems especially regarding water and electricity resources.

ANNEXURE A

ANNEXURE B

ANNEXURE A: DEVELOPMENT COST SUMMARY

DESCRIPTION	BULK SERVICES COST	INTERNAL SERVICE COST	SUB TOTAL
ROAD INFRASTRUCTURE			
UPGRADING OF TR 2/1	30 800 000,00	-	30 800 000,00
ROUNDABOUTS ON TR 2/1	13 200 000,00	-	13 200 000,00
INTERNAL ROADS	-	131 200 000,00	131 200 000,00
PUBLIC PARKING AREAS	-	16 400 000,00	16 400 000,00
PUBLIC WALKWAY AND CYCLING LANES	-	16 400 000,00	16 400 000,00
SUB-TOTAL ROAD INFRASTRUCTURE	***44 000 000,00***	***164 000 000,00***	***208 000 000,00***
STORMWATER INFRASTRUCTURE			
STORMWATER INFRASTRUCTURE	-	22 000 000,00	22 000 000,00
SUB-TOTAL STORMWATER INFRASTRUCTURE	***-***	***22 000 000,00***	***22 000 000,00***
WATER INFRASTRUCTURE			
BULK WATER SUPPLY LINE	27 500 000,00	-	27 500 000,00
INTERNAL POTABLE WATER SUPPLY		9 500 000,00	9 500 000,00
INTERNAL FIRE RETICULATION	-	600 000,00	600 000,00
IRRIGATION SYSTEM	-	-	-
SUB-TOTAL WATER INFRASTRUCTURE	***27 500 000,00***	***10 100 000,00***	***37 600 000,00***
SEWER INFRASTRUCTURE			
SEWER LINES AND MANHOLES	-	14 450 000,00	14 450 000,00
SEWER PUMP STATION AND RISING MAIN		6 800 000,00	6 800 000,00
TRICKLING FILTER PLANT	67 750 000,00	-	67 750 000,00
SUB-TOTAL SEWER INFRASTRUCTURE	***67 750 000,00***	***21 250 000,00***	***89 000 000,00***
SOLID WASTE MANAGEMENT			
PROVISION FOR MINOR SOLID WASTE FACILITIES	2 000 000,00	-	2 000 000,00
SUB-TOTAL SOLID WASTE INFRASTRUCTURE	***2 000 000,00***	***-***	***2 000 000,00***
ELECTRICAL INFRASTRUCTURE			
NETWORK CONTRIBUTION	16 000 000,00	-	16 000 000,00
MAIN POWER SUPPLY CABLE	13 800 000,00	-	13 800 000,00
SWITCHING STATION	6 700 000,00	-	6 700 000,00
INTERNAL MV	-	29 300 000,00	29 300 000,00
INTERNAL LV	-	13 300 000,00	13 300 000,00
STREET LIGHTS	-	9 600 000,00	9 600 000,00
SUB-TOTAL ELECTRICAL INFRASTRUCTURE	***36 500 000,00***	***52 200 000,00***	***88 700 000,00***
MARINA AND ASSOCIATED BREAK WATER INFRASTRUCTURE			
MARINA	-	75 000 000,00	75 000 000,00
BREAK WATER STRUCTURE		15 000 000,00	15 000 000,00
SUB-TOTAL MARINA AND BREAKWATER INFRASTRUCTURE	***-***	***90 000 000,00***	***90 000 000,00***
SUB TOTAL DEVELOPMENT COST	**177 750 000,00**	**359 550 000,00**	**537 300 000,00**
ADD 10% CONTINGENCY	**17 775 000,00**	**35 955 000,00**	**53 730 000,00**
ADD 15% VAT	**29 328 750,00**	**59 325 750,00**	**88 654 500,00**
SUB TOTAL DEVELOPMENT COST	**224 853 750,00**	**454 830 750,00**	**679 684 500,00**



ANNEXURE B:

PROPOSED DESERT ROSE DEVELOPMENT LAYOUT SKETCH

WCE

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DESIGNED		APPROVAL BY CLIENT	
DRAWN	B.O. Bravenboer		
APPROVED FOR WCE	B.O. Bravenboer	DATE	
DATE :	SEPTEMBER 2013	SCALE	NOT TO SCALE
CONSULTANT DRAWING NO.		CLIENT DRAWING NO.	
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REVISIONS	0										SHEET SIZE	A3