DISPERSAL OF YOUNG AFRICAN BLACK OYSTERCATCHERS (HAEMATOPUS MOQUINI) MOVEMENT PATTERNS, INDIVIDUAL CHARACTERISTICS, HABITAT USE AND CONSERVATION IMPLICATIONS

ANURADHA SHAKUNTALA RAO

DISPERSAL OF YOUNG AFRICAN BLACK OYSTERCATCHERS (*HAEMATOPUS MOQUINI*):

Movement Patterns, Individual Characteristics, Habitat Use and Conservation Implications

by

© Anuradha Shakuntala Rao, B.A.Sc.

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Abstract

The African Black Oystercatcher (*Haematopus moquini*) is a shorebird endemic to southern Africa, and is internationally listed as "*Near-threatened*". Its population is increasing following protection measures and the invasion of the mussel *Mytilus galloprovincialis*. Although adults of the species are sedentary, dispersal up to 2800 km by immature birds was discovered in 1998. To ensure that conservation programs address the species' needs throughout its life cycle, this project determines the locations of importance to oystercatchers between the start and end points of their dispersal.

Young African Black Oystercatchers disperse to a range of traditional locations along the coasts of South Africa and Namibia. Dispersal roosts along the Atlantic coast allow young birds to avoid competition for food with adults. Of the total number of South African-bred birds (n = 106) whose dispersal endpoints were confirmed, 65% dispersed to Namibia, 11% to north-western South Africa, 19% within south-western South Africa, and 5% dispersed along the south coast of South Africa. At least 22% of resighted birds departed in their first year of life, and 25% returned to the vicinity of their natal sites in their third or fourth year of life. At least 4% dispersed later than their first year. Body condition, sex and relative hatch date did not differ significantly between immature oystercatchers dispersing different distances.

Roosts were mostly, but not exclusively, located in wave-sheltered areas containing both rocky and sandy substrata and with wide visibility angles allowing for vigilance against predators. The birds fed in the immediate vicinity of the roost sites at low tide. The largest roosts were in sheltered areas near river mouths; these sites were

characterized by lower limpet numbers than smaller roosts. All but one roost checked also contained other shorebird and seabird species.

Because these sites are traditional and used by several species for various purposes during a sensitive time of the oystercatchers' life cycle, they are important for conservation. However, several roost sites are located in areas zoned for diamond mining or development. Diamond mining can, at least temporarily, reduce the local abundance of oystercatcher prey, thereby eliminating the area as foraging habitat. Ribbon development on the coast should be discouraged to maintain undisturbed habitats, and coastal mining and mining-related activities should not be allowed in areas used by roosting or foraging shorebirds.

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Status of Publications and Co-Authorship Statement

Publications:

Chapter 2: Rao, A.S., Hockey, P.A.R. and Montevecchi, W.A. Coastal dispersal by young African Black Oystercatchers *Haematopus moquini*. Submitted to Journal of Field Ornithology.

Chapter 3: Rao, A.S., Hockey, P.A.R., Wieters, E.A., Montevecchi, W.A. and Edinger, E.N. Habitat characteristics and conservation along the dispersal route of the African Black Oystercatcher *Haematopus moquini*. To be submitted to Animal Conservation.

Chapter 4: Rao, A.S. and Hockey, P.A.R. Conservation threats to African Black Oystercatcher (*Haematopus moquini*) roosts on the South African and Namibian Atlantic coasts. To be popularized and submitted to Africa Birds and Birding or African Wildlife.

Appendices and supplements referred to in the chapters are for the purposes of this thesis only, and are not being submitted for publication.

Co-Authorship Statement

- *Design and identification of the research proposal*

The primary design of the project was by Professor Philip Hockey of the University of Cape Town. From the many ideas presented to me, I narrowed down the focus of the project and placed emphasis on its conservation-related aspects.

- *Practical aspects of the research*

Unless otherwise mentioned (e.g. in historical information on oystercatchers and the collection of mollusc data), I conducted the primary research for this project. I received assistance initially from Philip Hockey and Douglas Loewenthal in getting oriented on the project and the primary tasks involved, however I was primarily responsible for the logistics of carrying out the research, including field trips and data collection.

- *Data analysis*

I performed all the data analyses presented in this thesis.

- *Manuscript preparation*

I prepared the thesis and all manuscripts contained herein, with editorial input from Professor Philip Hockey of the University of Cape Town, and Drs. Evan Edinger and William Montevecchi of Memorial University of Newfoundland.

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Chapter 1
Introduction and Overview

This thesis is about the dispersal and conservation of young African Black Oystercatchers (*Haematopus moquini*), a *Near-threatened* species (BirdLife International 2004), found primarily on the west coasts of South Africa and Namibia (Figure 1.1). Hockey *et al.* (2003) concluded that some South African-bred juveniles of the species 'migrate' once in their lives, from their natal sites to endpoints in Namibia, while others do not. Start and end points of the birds' movement were identified, however any sites used by the birds en route to the endpoints, and their protection status, were unknown. The identification of sites that African Black Oystercatchers use for roosting and staging during their movements is important in order to better understand the species' life history strategy and population dynamics. It is also important to clarify whether the movement pattern is more characteristic of post-fledging dispersal or migration. It is of conservation concern if roost sites are traditional or selected based on certain habitat characteristics and are currently or potentially threatened. If sites are chosen randomly, then the birds are opportunistic and may be able to adapt and use alternative roost sites.

This chapter first presents definitions of migration and dispersal terminology used in the thesis. Brief considerations of shorebird habitat conservation and oystercatcher distributions worldwide precede more details about the African Black Oystercatcher and its biogeographical context. The introduction ends with an outline of the aims, objectives and hypotheses that form the foundation of the thesis. Chapter 2 addresses the species' dispersal pattern, and examines whether certain characteristics differentiate birds travelling different distances. Chapter 3 analyzes habitat features at high-tide roosts along the travel route, discusses conservation threats to these areas, and makes recommendations for further protection. Chapter 4 addresses these conservation threats and recommendations in more detail. Chapter 5 summarizes the conclusions of the study. Supplementary information is provided in appendices, which are referred to throughout the document.

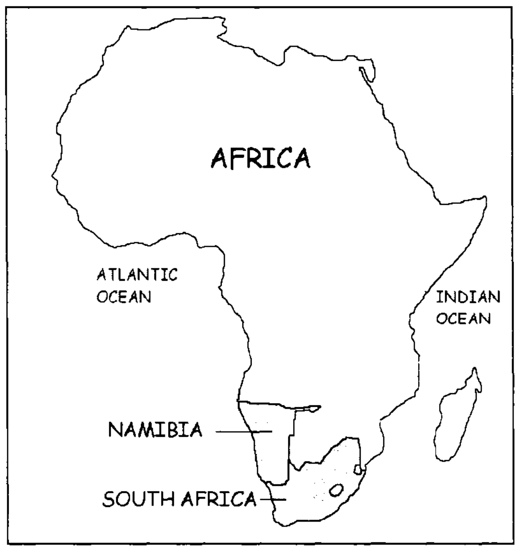


Figure 1.1. Locations of the focal countries, South Africa and Namibia, within Africa

Shorebird Movement Definitions

With respect to African Black Oystercatcher movement patterns and conservation, it is necessary to clarify the meanings of various migration-, dispersal- and shorebird-related terms used in this document.

Communal Roost

A communal roost has been defined as a place where many animals, which have been feeding solitarily or in groups, converge to rest or sleep (Ward and Zahavi 1973). The adaptive purposes of communal roosting can include thermoregulation (Bremner 1965, Francis 1976); predator avoidance through the ability to detect a predator sooner and take flight more quickly (Lack 1966, Ydenberg and Prins 1984); or as an information centre to find prey locations (Ward and Zahavi 1973, Krebs 1974). For the purposes of my study, I define a roost as an aggregation of birds at high tide.

Endpoint

For the purposes of this study, a migration or dispersal endpoint is described as the furthest distance an individual bird travels from its natal site.

Migration

Although a narrow definition of migration is the regular, seasonal to-and-fro movements by birds between their breeding and wintering sites (Schüz *et al.* 1971), a wider definition of migration is more appropriate for this project. Such a definition may encompass dispersal movements (Berthold 2001). Kennedy (1985) defines migration as "persistent and straightened-out movement effected by the animal's own locomotory exertions or by its active embarkation on a vehicle. It depends on some temporary inhibition of station-keeping responses, but promotes their eventual disinhibition and recurrence." Dingle (1996) clarifies that this definition of migration does not emphasize the length or repetition of the journey, but rather focuses on the characteristics of the behaviour itself. He suggests that to determine whether an individual is a migrant, it should "manifest reciprocal interactions between ranging and station keeping responses on the one hand and migratory responses on the other" (p. 26). He also mentions that animal migrants do not respond to the presence of food or shelter while in transit, that is, they do not terminate their journey prematurely in response to immediate resource availability.

Partial migration

Partial migration is a phenomenon whereby part of a population or species migrates, and part stays on the breeding grounds. This pattern is widespread among birds (Berthold 1999, Berthold 2001). Many species that were previously considered to be either exclusively sedentary or exclusively migratory have since been found to be partial migrants (Rappole 1995, Berthold 1999). It generally occurs in cases where the evolutionary advantages and disadvantages of migration or remaining sedentary are roughly equal. Hypotheses relating to both endogenous (genetic) and exogenous forcing factors have been proposed to explain the factors controlling partial migration, although evidence is strongest for genetic control of the behaviour (Berthold and Querner 1982, Biebach 1983, Dhondt 1983, Chan 1994, Berthold 1984, Adriaensen *et al.* 1993).

Post-Fledging Dispersal

Dispersal may be defined as a one-way movement resulting from active centrifugal movements. In birds, this is particularly common among juveniles, and mostly occurs within a few months after fledging. Potential functions of this type of dispersal include avoidance of competitors, regulation of density and adaptation to fluctuations in population size, avoidance of inbreeding, establishment of new breeding areas and responses to changes in food conditions (Berthold 2001). A second definition of dispersal involves a two-way movement, and thereby does not serve the purpose of finding new breeding areas. Some birds that disperse after fledging eventually return to their natal sites to breed (Nelson 1978, Marchant and Higgins 1990, Crawford *et al.* 1995, Whittington 2002).

Staging site / Stopover site

A staging or stopover site can be defined as a refuelling point between migratory or dispersal flights (Erni *et al.* 2002). Flights tend to be briefer than the time spent at the refuelling points (Hedenström and Alerstram 1997). The birds' migration or dispersal schedule may coincide with factors such as prey availability and lack of predators at stopover sites. For example during spring migration, thousands of shorebirds gather in Delaware Bay at the same time as the spawning of their prey, the horseshoe crab *Limulus* *polyphemus* (Tsipoura and Burger 1999). Also, southward-migrating Western Sandpipers (*Calidris mauri*) with high fat reserves stop to feed at large open sites which are safe from predators, whereas those with low body fat stop at more dangerous sites that offer superior energy intake rates (Ydenberg *et al.* 2002).

Shorebird Habitat Conservation

Many shorebirds are migratory, and some travel continental-scale and longer distances (Williams and Williams 1990). Many exhibit high levels of site fidelity to breeding, staging and wintering sites year after year (Hayman *et al.* 1986, Berthold 2001). Unfortunately, shorebird habitats around the world are often threatened by activities including climate change (sea level rise), pollution, developments (Cayford 1993), human recreational activities (Fox *et al.* 1993, Schulz and Stock 1993) and harvesting of their prey (Goss-Custard *et al.* 2004).

Because shorebirds congregate at high-tide roost sites and migration stopover sites, a sub-population or an entire population of a species may be vulnerable to disturbance at certain times. Disturbances at roost sites can have negative consequences because of the generally limited space along a coastline at high tide for large numbers of shorebirds to congregate, as well as increased energy expenditure due to flush flights, and reduced time for preening and resting (Harrington 2003). Frequent disturbances have been shown in some cases to compel shorebirds to abandon traditional roosts (Smit and Visser 1993). Loss of foraging habitat along a dispersal or migration corridor can result in reduced time for feeding if foraging habitat is limited or feeding opportunities are otherwise naturally restricted (Cayford 1993, Fox *et al.* 1993). Although birds can feed at times when disturbance is less or move to less disturbed foraging areas if enough suitable habitat exists (Goss-Custard and Verboven 1993), chances of survival may be reduced if this leads to increased bird densities and therefore decreased rates of food acquisition (Goss-Custard 1980).

High disturbance levels also reduce the quality of potential breeding habitats (Schulz and Stock 1993). Shorebirds' nests are shallow and often located in areas frequented by humans, and are therefore prone to trampling, flooding, mammalian predation and habitat loss (Knox *et al.* 1994, Leseberg *et al.* 2000, Plissner and Haig, 2000, Goossen *et al.* 2002). Piping Plovers (*Charadrius melodus*) in North America and Kentish Plovers (*Charadrius alexandrinus*) in Europe show low reproductive success due to predation, human disturbance and habitat loss to development (Cairns and McLaren 1980, Haig 1985, Dyer *et al.* 1988, Flemming *et al.* 1988, Patterson *et al.* 1991, Schulz and Stock 1993).

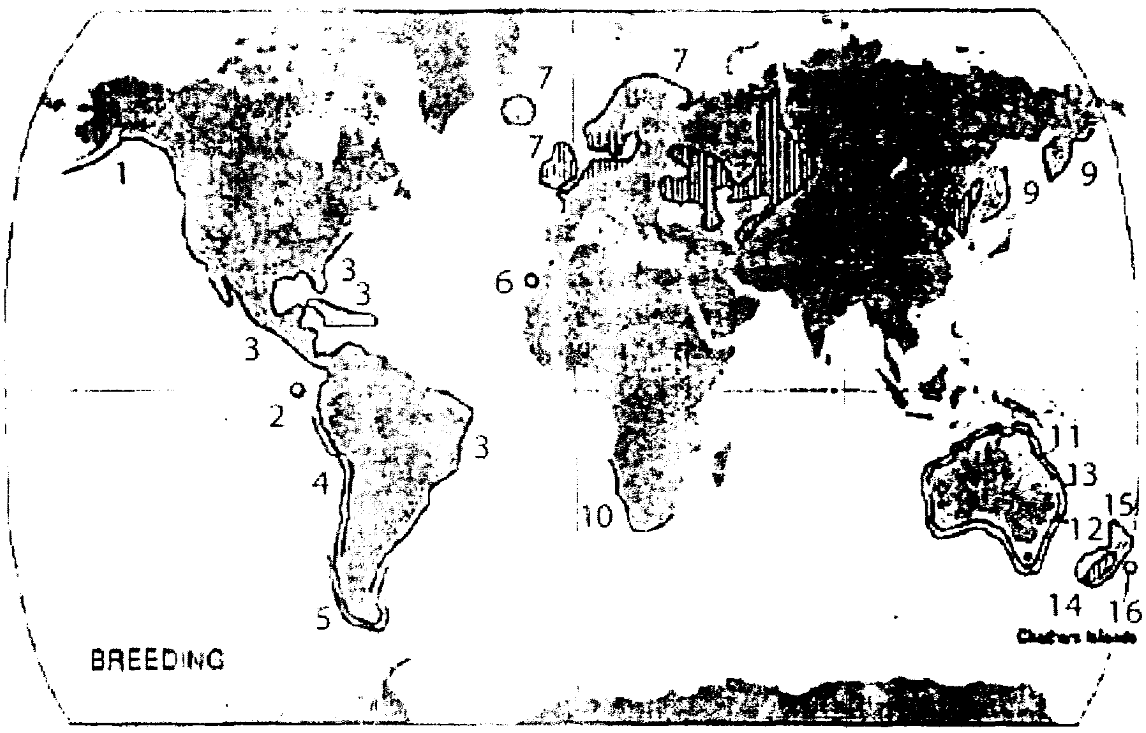
Shorebird conservation requires a landscape-level approach, because shorebirds use several habitat types at different times, in different locations and along their migration and dispersal routes. African Black Oystercatchers, for example, use sandy or shelly beaches, rocky shores, offshore guano islands and mudflats at various stages during their lifetimes (Hockey 1983b, Hockey 1985, Leseberg 2001).

Oystercatchers around the World

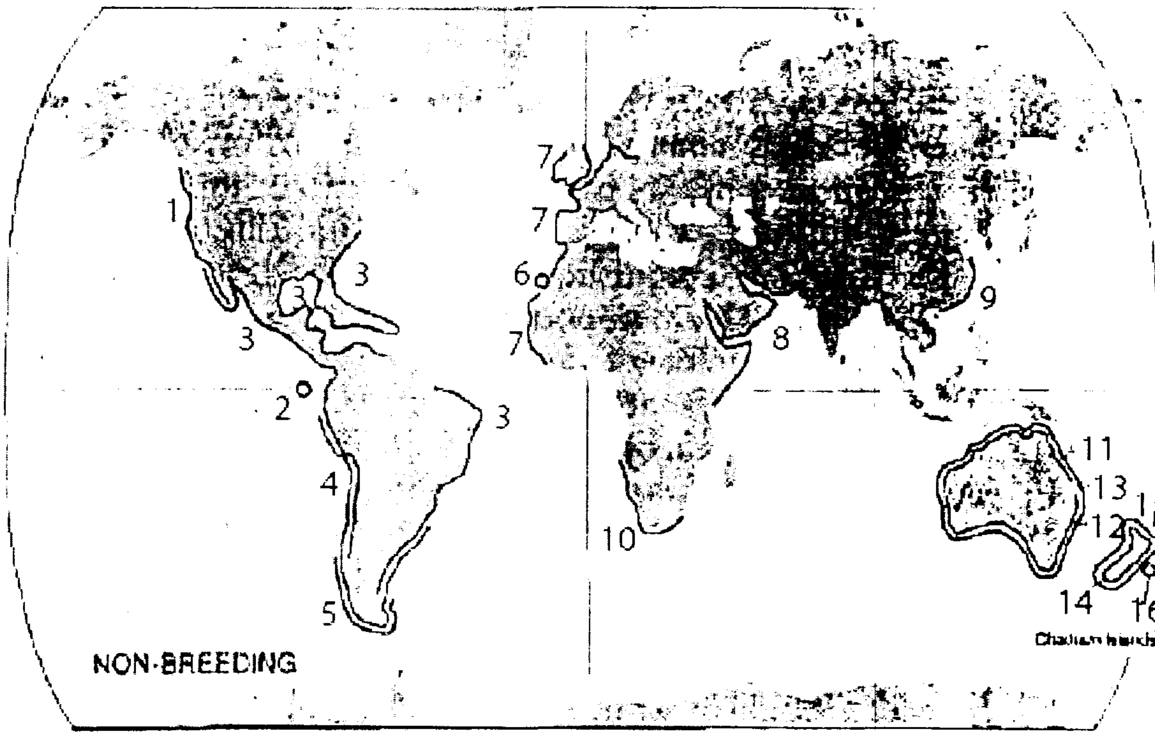
Distribution and species

Eleven extant species of oystercatcher (*Haematopus*) (Hockey 1996a) can be classified into four regionally based categories: Nearctic/Neotropical, Palearctic, Afrotropical and Australasian (Figure 1.2 and Table 1.1) (Hockey 1996b).

Figure 1.2. a) Breeding (this page) and b) non-breeding (next page) distributions of the world's oystercatchers (from Hockey 1996b) 1 = *H. bachmani*, 2 = *H. palliatus galapagensis*, 3 = *H.p. palliatus*, 4 = *H. ater*, 5 = *H. leucopodus*, 6 = *H. meadewaldoi*, 7 = *H.ostralegus ostralegus*, 8 = *H.o. longipes*, 9 = *H.o. osculans*, 10 = *H. moquini*, 11 = *H. ophthalmicus* = 12 = *H. fuliginosus* (there is currently insufficient evidence to separate 11 and 12), 13 = *H. longirostris*, 14 = *H.o. finschi*, 15 = *H. unicolor*, 16 = *H. chathamensis*



a) Breeding distribution of oystercatchers



b) Non-breeding distribution of oystercatchers (continued from previous page)

Table 1.1. Oystercatcher species and causes of breeding failure around the world (from Hockey 1996a, 1996b)

Classification (Region)	Species	Causes of breeding failure
Nearctic and Neotropical	*H. bachmani*	Predation (gulls, crows), storms, humans, seals
	H. p. palliatus	Predation, high tides, flooding, storms, human encroachment, habitat loss
	H. p. galapagensis	Predation (mockingbird)
	H. leucopodus	
	H. ater	Predation (gulls, skuas)
Palearctic	*H. o. ostralegus*	Human disturbance, agriculture
	H. o. longipes	
	H o. osculans	
	H. meadewaldoi	*Almost certainly extinct*
Afrotropical	*H. moquini*	Predation (gulls, mammals), storms, human disturbance
Australasian	*H. longirostris*	Predation (ravens), humans, domestic animals, high tides
	H. fuliginosus / H. ophthalmicus	Predation (gulls)
	H. unicolor	
	H. chathamensis	*Endangered*
	H. o. finschi	Agriculture

Habitat conflicts and threats

Long-term breeding and non-breeding site fidelity is a common characteristic among several oystercatcher species (Hockey 1996b). Oystercatcher breeding success is low worldwide. Known threats to the breeding success of various species of oystercatchers are summarized in Table 1.1 (Hockey 1996a, 1996b). Other negative effects of human activities on oystercatchers include habitat loss due to increased human population and developments on beaches, in estuaries and in shallow coastal bays; eutrophication and pollution of estuarine and coastal waters, leading to contamination of waters and smothering of prey sources; shellfisheries and bait-digging, causing disturbance and reducing food availability; disturbance through deliberate actions, leisure activities, aircraft, seismic research, drilling, military practices and scientific research; and shooting (Lambeck *et al.* 1996).

Migration

Migration in oystercatchers is rare. Only two oystercatchers are significantly migratory: the Eurasian Oystercatcher (*H. ostralegus*) and, to a much lesser extent the American Black Oystercatcher (*H. bachmani*). Both young and adults of these species migrate. They likely migrate in autumn due to food shortages resulting from low winter temperatures, as well as intra-specific competition. Eurasian Oystercatchers tend to exhibit 'leapfrog migrations', meaning that migrating birds will skip over areas closer to their breeding areas containing resident birds to endpoints further away. This is likely due to a competitive advantage accruing to birds which are resident year-round in areas that could serve as wintering grounds (Hulscher *et al.* 1996).

The African Black Oystercatcher (*Haematopus moquini*)

Distribution and breeding

The breeding range of African Black Oystercatchers (*Haematopus moquini*) extends from Lüderitz, Namibia (26°38'S, 15°10'E) to Port Edward, South Africa (31°03'S, 30°14'E) (Hockey 1983b, Neville 1999). Non-breeding individuals have been sighted as far northwest as Lobito, in southern Angola (Hockey 1983b) and as far northeast as Inhaca Island, Mozambique (de Boer and Bento 1999). Seventy-five percent of the resident population is in South Africa (Oystercatcher Conservation Programme, unpublished data). The species' breeding range has expanded eastwards by approximately 300 km in the last 20 years, moving into the eastern biogeographic zone of the southern African region, which is warm and tropical (Vernon 2004). Previously, its most easterly known breeding location was Mazeppa Bay (32°28'00"S, 28°38'60"E) (Skead 1967, Summers and Cooper 1977). The expansion in breeding range is hypothesized to have resulted from emigration of individuals from the core population, due to an increase in the species' overall population size. It may also reflect variability in prey abundance (Vernon 2004).

The species breeds only on the coasts and offshore islands of South Africa and Namibia (Oystercatcher Conservation Programme, unpublished data). Thirteen of 14 seabirds in southern Africa, as well as shorebirds such as the oystercatcher, breed on offshore islands, which historically lacked native mammalian predators (and most still do) (Cooper *et al.* 1985). Breeding on islands results in reduced risk of losing eggs or chicks to mammals (Summers and Cooper 1977, Hockey 1983a).

The breeding season of *H. moquini* generally lasts from November to March. They have low reproductive rates (clutch size of 1-2 eggs, rarely three) (Hockey 1983a); therefore any increase in mortality can potentially have large population-level consequences. African Black Oystercatchers exhibit high natal philopatry, i.e. they typically return to, or very close to, their natal sites after post-fledging dispersal. Pairs also breed in the same territory from year to year and are monogamous (Hockey 1996a).

Feeding

African Black Oystercatchers feed exclusively in the intertidal zone, often on rocky shores (Hockey 1996b). The range of prey consumed by the African Black Oystercatcher is among the broadest of any oystercatcher and includes at least 54 species of marine invertebrate (Hockey and Underhill 1984, Hockey 1996b, Leseberg 2001). Prey consumed on rocky shores includes mussels, limpets, whelks and winkles (Hockey 1996b). Sandy shore prey includes mussels *Donax serra and D. sordidus* (Hockey 1996a). Since the 1980s, the invasive Mediterranean mussel *Mytilus galloprovincialis* has replaced indigenous species, for example the ribbed mussel *Aulacomya ater*, along the south and west coasts of South Africa and the west coast of Namibia and has become the dominant intertidal bivalve on these coasts. It is faster-growing, more fecund and more desiccation-tolerant than indigenous mussel species (Hockey and van Erkom Schurink 1992, Hockey 1996b). Although this has resulted in undesirable changes to the coastal landscape and ecosystem (van Erkom Schurink and Griffiths 1990) *M. galloprovincialis* now makes up 65-75% of the oystercatcher's diet on the west coast (Hockey 1996b).

Because of its complex feeding techniques, oystercatchers have been able to occupy a specialized foraging niche, hence they face low competition with other bird species for food (Safriel *et al.* 1996). In southern Africa, Kelp Gulls (*Larus dominicanus*) also prey extensively on mussels, but of different sizes (Griffiths and Hockey 1987). Hartlaub's Gulls (*L. hartlaubii*) have been observed to harass young oystercatchers during feeding (*pers. obs.*). The rocksucker fish (*Chorisochismus dentex*) also feeds on limpets (Branch *et al.* 1994). Major competitors for food are conspecifics. This is of particular importance to young oystercatchers, as they require several years to develop feeding techniques (Norton-Griffiths 1969).

Roosting

Like other oystercatcher species, African Black Oystercatchers form communal roosts at high tide during the non-breeding season (Hockey 1996b). Juveniles are known to form or join high-tide roosts toward the end of the breeding season. Roosts tend to be small, relative to those of other avian species, and increase in size as the tide rises and foraging areas become progressively inundated. Roost site fidelity is high (Hockey 1985).

Roosts are unlikely to function as information centres, because the birds are highly territorial (Hockey 1985). Nor are they likely to be important in annual mate acquisition, because the birds form long-term pair bonds (Hockey 1996a). Therefore the most plausible explanation for the evolution of communal roosting in the species is predator avoidance. Breeding oystercatchers do not roost communally during the breeding season, and mortality due to mammalian predators is highest during that season (Hockey 1985). Following the joining of Marcus Island, one of their breeding areas, to the mainland in 1976 for harbour development, eight potential species of predators were introduced to the island. Between 1979 and 1983 (when a 'predator-proof' wall was erected) 29 oystercatchers were killed by predators, with the majority (19) having been killed during the breeding season, when the birds would not have joined communal roosts providing anti-predator vigilance (Cooper *et al.* 1985). Because most of their predators are nocturnal, night roosts often were larger than day roosts (Hockey 1996b).

Oystercatcher roost sites studied in Namibia and South Africa between 1979 and 1982 possessed several common physical features. Seventy-six percent of west coast roost sites were adjacent to offshore rocks, to which the birds flew if disturbed from their mainland roost. Sixty-seven percent of west and southwest coast roosts were situated on promontories, and mostly sheltered from the weather relative to the adjacent coast. Six of eight south coast roosts were near river mouths. South-east coast roosts were generally in flat, open areas, with extensive visibility. Roost substratum was variable, but roosts were often situated on predominantly rocky coasts (Hockey 1985).

Post-fledging movements

The African Black Oystercatcher was previously considered to be among the most sedentary of oystercatcher species, with adults being non-migratory and juveniles dispersing no more than 650 km, and often less than 150 km, from their natal sites (to 'local dispersal roosts') (Hockey 1983b, Hockey *et al.* 2003). More recent resightings of individually colour-banded birds, however, have shown that some juveniles travel much further. Hockey *et al.* (2003) estimated that 36-46% of juveniles born in South Africa travelled 1500 to 2000 km from natal sites, to one of five discrete 'nursery' areas in central and northern Namibia, and southern Angola (see Figure 1.3). These areas are all north of the species' breeding range. Juvenile birds from the eastern part of the breeding range undertake what has been called 'diffusion dispersal', involving movements of up to 1000 km, but mostly ending within the species' overall breeding range, with some exceptions such as a bird that travelled over 2800 km from East London to Walvis Bay (Oystercatcher Conservation Programme, unpublished data).

Hockey *et al.* (2003) proposed that African Black Oystercatchers demonstrate a unique migration pattern. They concluded that some juveniles 'migrate' only once, remaining at the migration endpoint roosts for two to three years before returning to their natal sites where they remain sedentary for the rest of their lives. The remainder of the juveniles disperse within 150 km of their natal sites. Published records of a juvenile roost in Namibia have existed since the 19th Century (Gurney 1872), although the South African origin of some individuals at the roost were discovered only in 1998 (Tree 1998). It is possible that this movement is density-dependent and has increased with an increase in the oystercatcher population. Prior to my research, roost sites used by the birds between the South African breeding areas and movement endpoints in Namibia and Angola were largely unknown (Figure 1.3, Hockey *et al.* 2003).

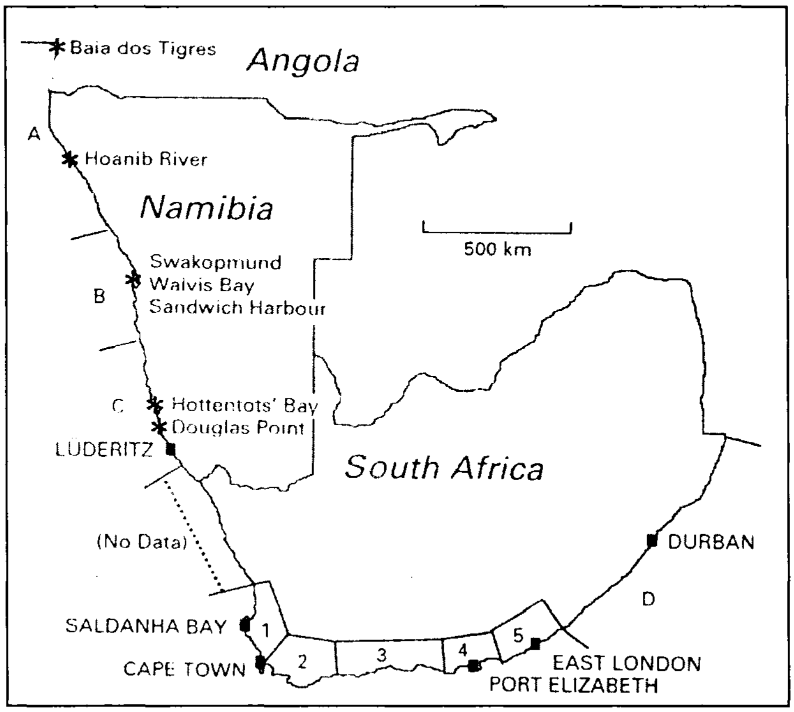


Figure 1.3. Locations of previously known oystercatcher juvenile movement endpoints (asterisks) and banding areas within the breeding range (numbered sections) (from Hockey *et al.* 2003)

Population dynamics, mortality and conservation

The African Black Oystercatcher is listed as *Near-threatened* in the IUCN Red List of threatened species (BirdLife International 2004). In the early 1980s, the world population of African Black Oystercatchers was about 4800 birds. Since then, numbers have increased to an as yet unquantified extent, but could be as high as 6000-7000 (Oystercatcher Conservation Programme unpublished data). It is unknown what the species' population size was before the 1980s, although genetic research is planned that could explain the population's historical trajectory. The invasion of *M. galloprovincialis* has benefited the oystercatcher by increasing food availability (Hockey and van Erkom Schurink 1990).

There are no published data regarding the lifespan of the African Black Oystercatcher, however breeding individuals over 30 years old have been recorded (Oystercatcher Conservation Programme, unpublished data). Eighty percent of chick mortality occurs within 20 days after hatching (Loewenthal 2004). Confirmed predators of the African Black Oystercatcher include Cape Foxes (*Vulpes chama*) (Halteworth and Diller 1980, Cooper *et al.* 1985) and feral cats (*Felis catus*) (Cooper 1977). Other potential predators include rats (*Rattus* sp.), Small Grey Mongoose (*Galerella pulverulentus*), Yellow Mongoose (*Cynictis penicillata*), Small-spotted Genets (*Genetta genetta*), and domestic dogs (*Canis familiaris*). Eggs are preyed upon by Water Mongoose (*Atilax paludinosus*) and Kelp Gulls (Summers and Cooper 1977).

A major threat to oystercatchers is human disturbance of breeding sites. The oystercatcher breeds during the height of the tourist season in South Africa, often on beaches heavily used by humans for recreational activities. While human activities tend not to destroy the oystercatcher's habitat *per se*, except perhaps in the major urban centres of Cape Town and Port Elizabeth, human disturbance of breeding sites can lead to exposure or drowning of unattended eggs and chicks. Over 50% of chick deaths occurring outside protected areas are due to human disturbance (Leseberg *et al.* 2000). The bird therefore tends to incur substantial losses of eggs and young during the tourist season (Oystercatcher Conservation Programme, unpublished data). The post-fledging dispersal route of the African Black Oystercatcher includes areas with low human population density, although diamond mining occurs along a large part. Extreme heat is known to have led to major breeding setbacks for the oystercatcher in two years, when temperatures during the incubation period exceeded 40°C (Oystercatcher Conservation Programme, unpublished data).

An Oystercatcher Conservation Programme has been established in South Africa, which involves researchers, conservation organizations and the general public. It aims to produce a model of the species' population dynamics, integrate the model with observed population changes and produce a scientifically defensible strategy for its conservation (Oystercatcher Conservation Programme, unpublished data). My research project falls within the context of this Programme.

Coastal Ecosystems in Atlantic South Africa and Namibia

South Africa

The west coast of South Africa differs from its south and east coasts in that it is cool and temperate, whereas the south coast is warm and temperate and the east coast is warm and tropical (Attwood *et al.* 2000). On the basis of rocky shore invertebrates, five major zoogeographic zones have been identified along the southern African coast. The west coast includes two of these zones (the northern and southern cool, temperate zones), split at Lüderitz, Namibia. Physiographically, the coast is very heterogeneous, due to interactions between factors such as wave action, sediment supply, climate, tectonics and sea level (Emanuel *et al.* 1992). Due to the strong upwellings of the Benguela Current, the southwest coast is a very organically rich environment (Leslie 2000). Important ecosystem types within the intertidal environment include rocky shores, sandy shores, estuaries and coastal islands (Attwood *et al.* 2000).

The coastal islands of South Africa (covering less than 2000 ha in total) are basically rocky, and have sparse or seasonal precipitation. Seal or seabird guano from the islands results in high nutrient loading into the surrounding inter- and sub-tidal waters, relative to mainland shores. This results in an increased algal growth rate, coupled with increased growth rates and sizes of herbivorous limpets. African Black Oystercatcher densities are higher on islands than on the mainland (Bosman and Hockey 1988). These islands also lack native terrestrial mammalian predators, and were free from human predators until the arrival of Europeans (Williams *et al.* 2000).

Seventeen percent of South African marine protists and animals are considered to be endemic or are known only from South African records (Gibbons 2000); the conservation status of many marine species is poor (Attwood *et al.* 1997).

Namibia

The arid and barren Namib Desert runs along the entire Atlantic coast of Namibia, resulting in largely sandy shores. The southern Namibian coast also is influenced by the Benguela Current (Pulfrich *et al.* 2003b). The 26 000 km^2 portion of southern Namibia from the Orange River, which forms the boundary between Namibia and South Africa, to Lüderitz, is known as the Sperrgebiet ('Forbidden Area'). The Orange River, forming the border with South Africa, is the only permanent water body in the area. The Sperrgebiet is characterized by low rainfall (less than 100 mm per year) and a long recovery time (vehicle tracks can remain for tens to hundreds of years). The southern Sperrgebiet is characterized by very mobile, coarse-grain beach sands, which are inhospitable to many shore-living animals (Pallett 1995).

Sensitive areas of the Sperrgebiet coast include:

- the Orange River Valley including the river mouth, a Ramsar site which is a home for resident and migratory birds;
- the coast and coastal dune hummocks, which are extensively mined but contain many endemic animals (Oranjemund to Lüderitz);
- Wolf Bay, Atlas Bay and North and South Long Islands, which house 40% of the world population of Cape Fur Seals (*Arctocephalus pusillus*);

- offshore islands, Elizabeth Bay and Hottentots Bay, which contain otherwise scarce breeding sites for seabirds such as Cape and Bank Cormorants (*Phalacrocorax capensis* and *P. neglectus*), Damara Terns (*Sterna balaenarum*), Cape Gannets (*Morus capensis*), African Penguins (*Spheniscus dermersus*) and shorebirds, including the African Black Oystercatcher (Pallett 1995).

Dominant intertidal biota in southern Namibia include the Cape reef worm (*Gunnarea capensis*), a few species of limpet in the sheltered intertidal zone, and the invasive mussel *Mytilus galloprovincialis* on the open coast (Pulfrich *et al.* 2003a). There has been little biological research in the Sperrgebiet, and no thorough assessment of animal diversity. Bird life in the area includes at least 10 coastal bird species, 25 migratory seabird species and 56 wetland bird species (Pallett 1995).

Aims of This Project

This project intends to fill some of the data gaps with regard to movements of young African Black Oystercatchers, with the ultimate goal of recommending appropriate conservation measures for the species along its travel route. In particular, I identify oystercatcher roost sites on the west coast between dispersal roosts within 150 km of major breeding areas and known movement endpoints in Namibia (see area marked "no data" in Figure 1.3). Through resightings of individually-marked birds, I attempt to unravel details of the timing of the birds' movement with respect to the species' life cycle, and characteristics that differentiate birds travelling different distances. Finally, I define what habitats are important for the species along the travel route, and discuss how these habitats might be most appropriately conserved given the human activities in their vicinities.

Objectives and Hypotheses

Objective 1: To quantify the movement patterns of juvenile African Black Oystercatchers and to identify locations important to these movements, either as staging areas or endpoints

To monitor and conserve this species effectively, it is necessary to identify all those sites that are important to it, particularly those sites where aggregations of the bird occur. Basic information on the locations of important sites will provide important baseline information in the event of future site loss, or other threats.

Hypotheses:

1a) Oystercatchers born in South Africa use roost sites along the South African and Namibian coastlines

Roost sites, as aggregation sites for a subset of a population, serve as important areas for shorebirds. Because oystercatchers born in south-western South Africa have been resighted at 'nurseries' up to and over 2000 km from their natal sites, they will likely have to stop at sites between those areas during their movements. The identification of these sites will inform conservationists as well as resource users which coastal areas are important to this species and potentially others.

1b) A single roost site may characterize a movement endpoint area for some individual birds and a stopover area for others

Prior to this study, it was not known which birds would be found at roosts in between the known local dispersal roosts and the 'migration' endpoint roosts in Namibia, and it was hypothesized that the nurseries in central and northern Namibia and southern Angola were the only endpoints for 'migratory' oystercatchers. To characterize how important a particular site is, it is necessary to know how the birds use the site.

1c) The same roost sites are used year after year by different cohorts of birds

There appears to be limited availability of suitable roosting and foraging habitat in the more northwesterly areas of South Africa and the coast of Namibia, and this may limit the oystercatchers' choice of roost sites. Researchers have monitored roost sites within roughly 150 km of the breeding area for the last 25 years. During that time, the only roost that disappeared did so because the roost site was physically destroyed by human construction, suggesting that the sites are traditional. Furthermore, the aggregation at Walvis Bay, Namibia is known to have existed since the mid-1800s (Gurney 1872).

1d) Roost sites used on outward movement are the same as those used on return

If roost sites are limiting and traditional, birds are predicted to use the same roosts on their outward and return journeys.

1e) Oystercatchers depart during their hatch year and return in their third or fourth year

Previous research suggested this pattern (Leseberg 2001), but this conclusion was based almost entirely on data from Walvis Bay and Swakopmund, Namibia and has not been verified with studies of birds using more southerly roosts.

Objective 2: To examine possible reasons why some birds travel further than others

Movement distance of young African Black Oystercatchers may be determined by measurable ecosystem-level drivers or individual characteristics. Determining what these are might suggest how changes in population dynamics may have led to a certain pattern.

Hypotheses:

2a) Birds travelling further had a better body condition as chicks

Previous research showed that those oystercatchers which travelled to central Namibia had higher body mass as chicks than those birds that undertook shorter-distance dispersal (Hockey *et al.* 2003). My research will reanalyze the data with a larger sample size and more inclusive range of distances travelled. It will also compare body condition indices (body mass in grams/tarsal length in millimetres) of birds travelling different distances.

2b) Movement distance is sex-specific

Sex data have only been acquired for banded African Black Oystercatchers in the last few years. The possibility of sex-biased movement is tested.

2c) Birds travelling further hatched later in the season

Because adults are territorial year-round, and because population size is largest at the end of the breeding season, it is possible that long-distance movements are density-dependent responses to a shortage of suitable foraging sites for juveniles close to the natal site. Given the energetic cost associated with long-distance movement, it is hypothesized that those juveniles dispersing early in the year from the parental territory will occupy the 'best' available sites first, forcing later-fledged birds to travel increasingly far. If resources further north become increasingly scarce and patchy (for example along the mostly sandy beaches of the Namib Desert coast), young birds may form large aggregations at the more northerly endpoints.

2d) Birds of different origins mix along the movement route, i.e. they use the same stopover and endpoint areas along the (linear) route.

Due to the perceived limited availability of suitable roosting and foraging habitat in the more northwesterly areas of South Africa and the west coast of Namibia, it may be expected that birds will use the same route and roosts to travel northwards. If birds from certain origins are found to choose certain sites, then the loss of these sites can have negative repercussions on birds from certain breeding areas.

Objective 3: To determine whether sites at which birds aggregate are characterized by a consistent suite of physical or biological characteristics

This analysis will show which habitat characteristics are important for site selection. It will also show whether there are many suitable sites along the coast, and examine whether the loss of a site might have negative consequences for the species. Particular emphasis is placed on roost sites, as these are areas where many birds congregate.

Hypotheses:

3a) Habitat features at roost sites differ from those at randomly selected sites where birds do not roost, and have characteristics that allow for both predator avoidance and access to food.

Oystercatcher roost sites on the southwest and southern shores of South Africa are close to promontories, offshore rocks and rivers, suggesting that sites are chosen based on the birds' need to avoid predators. West coast sites also are mainly on rocky shores (Hockey 1985), suggesting that nearby food availability also might influence roost site selection. If roost sites differ significantly from randomly selected sites not used as roosts, and therefore are chosen in a non-random fashion, their habitat characteristics may be factors limiting the distribution of the migratory population.

3b) Roost size increases significantly with the presence, or increased levels, of key habitat features

If certain features characterize suitable roosting habitat, it can be hypothesized that sites containing these characteristics will support greater numbers of birds than will 'inferior' roost sites. Sites with more of these characteristics could then be considered of greater significance for the species.

Objective 4: To assess whether any key sites have been or are threatened by human activities

This information can be used to inform resource users of the presence of the birds and suggest mitigation measures with regard to potentially harmful activities. The examination of human threats to the coastline as they may impact this species may also be extendable to other species and to coastal ecosystems as a whole.

Hypothesis:

4a) Roost sites fall within disturbed areas of the coastline

In Western Cape Province, which contains a large proportion of the species' population, there are several coastal protected areas providing varying degrees of ecosystem and species protection. There are few in Northern Cape Province, along which many juveniles travel and roost. Several human activities, including housing developments and diamond mining, occur along the oystercatchers' post-fledging travel route. To determine which conservation threats the species might face, and what impacts human developments may be causing along the coast, it is necessary to assess whether or not these activities are occurring in key areas used by oystercatchers (and other birds).

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Chapter 2
Coastal Dispersal by Young African Black Oystercatchers *Haematopus moquini*

Abstract
*African Black Oystercatcher (*Haematopus moquini*) roost sites were located and mapped along the Atlantic coasts of South Africa and Namibia. Nearly all roosts checked contained juvenile and/or immature, individually colour-banded birds. A series of dispersal endpoints are identified along the coastline, with the largest roosts being in central Namibia. Birds forage at or near the roost sites at low tide. Of the total number of birds (n = 106) whose dispersal endpoints were confirmed, 65% dispersed to Namibia (north of Lüderitz), 11% dispersed to north-western South Africa, 19% dispersed within south-western South Africa, and 5% dispersed along the south coast of South Africa. At least 22% of resighted birds departed in their first year of life, and 25% returned in their third or fourth year of life. Body condition, sex and relative hatch date were not significantly different for oystercatchers travelling different distances. Immature birds of different ages and origins mixed at roost sites along the dispersal route.*

Key words: *African Black Oystercatcher, juvenile dispersal, partial migration, shorebirds, southern Africa*

Introduction

Understanding species' movements is of critical importance in understanding population biology and ecology (Horn 1983, Horn and Rubenstein 1984). Movements such as long-distance dispersal, however, are often not understood well (van Balen and Hage 1989, Clobert and Lebreton 1991, Hansson 1991), and the distinction between different types of movements, particularly migration and dispersal, can be unclear (Dingle 1996). This is understandable given the idea that migrating birds evolved from sedentary ancestors (Rappole 1995), perhaps via juvenile dispersal, partial migration or nomadism (Merkel 1966, Baker 1978, Terrill 1991, Berthold 2001).

Migration allows species continuous access to spatially or temporally variable resources (Dingle 1996) and thereby allows them to survive changing environmental conditions (Berthold 2001, Winkler 2005). A separation of ages or sexes through differential migration, which can include migration over different distances, may also occur to reduce intra-specific competition, particularly in short- or medium-distance migrants (Gauthreaux 1982, Terrill and Able 1988, Gill *et al.* 1995). Reasons for dispersal (post-fledging dispersal in the case of birds) include avoidance of competition due to limited food availability (Adamcik and Keith 1978, Houston 1978), territorial disputes, and exposure to new antigens to combat parasites (Berthold 1999).

Both migration and dispersal come with risks of mortality (Hockey *et al.* 1998, Sillett and Holmes 2002) due to unfamiliar habitats, traversal of areas with high predator densities and physiological costs of the movement itself (Waser *et al.* 1994, Plissner and Gowaty 1996). The longer the distance travelled, the greater the risks (Bengtsson 1978, Sutherland *et al.* 2000). It may be assumed that the advantages of migration and dispersal outweigh their risks for further-travelling individuals.

Migration among oystercatcher species is rare. Only two oystercatchers worldwide are significantly migratory: the Eurasian Oystercatcher (*Haematopus ostralegus*) and the American Black Oystercatcher (*H. bachmani*). During summer, Eurasian Oystercatchers must find food in close proximity to their breeding sites but in winter, when they are not breeding, they must both escape the cold and avoid areas that contain resident oystercatchers, due to resident birds' competitive advantage (Hulscher *et al.* 1996). Only northern populations (i.e. in colder climates) of American Black Oystercatchers migrate long distances, with immature birds and adults migrating together (Andres and Falxa 1995). In contrast, generally warmer climatic conditions allow adult African Black Oystercatchers (*Haematopus moquini*) to remain in their breeding areas throughout the year.

The African Black Oystercatcher is not a true migrant according to the strict definition of the term, because the entire population does not migrate seasonally. What was originally thought to be partial juvenile 'migration' in the African Black Oystercatcher was discovered in 1998. Hockey *et al.* (2003) estimated that 36-46% of South African-bred juvenile African Black Oystercatchers travel in their first year of life to traditional sites in Namibia, returning to their natal areas only in their third or fourth year, and stopping at one or more unidentified sites during departure and return. They suggested that body condition, represented by body mass at hatching, differentiated migrants from non-migrants, with the former being in better condition. In this study, I use a larger data set to assess differences among young oystercatchers travelling different distances.

The phenomenon described by Hockey *et al.* (2003) is similar to that of other bird species. For example, juvenile Australasian Gannets (*Sula serrator*) move up to 5000 km from their natal sites and remain at movement endpoints for 2 to 3 years (Wodzicki 1967). Young Cape Gannets (*Sula capensis*) move thousands of kilometres north of the species' breeding colonies, and outnumber adults at movement endpoints. Few adults travel over 500 km from their breeding site (Nelson 1978b). Juvenile Northern Gannets (*Sula bassana*) travel up to 6400 km in their first or second winter; travelling distance is generally more limited for older birds, although some sub-adults and adults also travel extreme distances in the winter (Nelson 1978a, Nelson 1979). This juvenile movement may be considered to be dispersal rather than migration (Nelson 1978b). Juvenile African Penguins (*Spheniscus demersus*) move up to 1900 km from their natal sites, and usually return to these sites to breed. Adults mostly remain within 400 km of their breeding areas (Crawford *et al.* 1995, Whittington 2002).

To describe and quantify the movement pattern of young African Black Oystercatchers, I present the locations of sites that they use between their natal areas in South Africa and dispersal endpoints in Namibia. In determining the distances travelled by the birds, I analyze a larger data set of oystercatcher resightings to assess whether sites along the coast are used as stopover points or endpoints in themselves, and whether they are used year after year. I also use this larger dataset to obtain further details on the timing of this juvenile movement phenomenon. I assess potential 'triggers' of dispersal, specifically whether body condition, sex or relative hatch date differ between individuals dispersing to different distances, and whether birds of different ages and origins use different sites. Finally, I compare this dispersal pattern with those of other oystercatcher species. The African Black Oystercatcher is a suitable study species for further elucidation of the pattern and triggers of post-fledging dispersal, because its range is both linear and concentrated in a small geographical region, relative to other mobile or migratory species.

Methods

Study area

Research was conducted on the west coasts of South Africa and Namibia in 2004 and 2005 (Figure 2.1). Data collected from 1999 to 2005 by other researchers affiliated with the University of Cape Town's Oystercatcher Conservation Programme (Leseberg 2001, Oystercatcher Conservation Programme, unpublished data) were also used for analyses.

Bird Banding

During the November 1998 to March 1999 breeding season, the Oystercatcher Conservation Programme (OCP) began banding chicks in a way that allowed birds to be individually identifiable in the field. The breeding range in South Africa was divided into banding regions, each assigned a different band colour (see Table 2.1 and Figure 2.1). Chicks were banded on the right leg with a short plastic coloured band, denoting year, over a short metal band engraved with a unique 6-digit code. On their left leg they were banded with a long plastic coloured band, denoting banding region and engraved with a unique 3-character code intended to be readable when observing the birds through a spotting scope. Culmen, tarsus, flat wing and body mass measurements were recorded and blood samples were collected from some banding areas for genetic sexing.

Table 2.1. Colour codes for banding regions and relative numbers of birds banded in each region

Region	Band Colour (Letter Code)	Number (percent) of birds banded as of June 2005
Lambert's Bay to Cape Point, including Robben Island	Blue (B)	109 (11)
Saldanha Bay islands	Yellow (Y)	352 (36)
Dassen Island	Orange (O)	279 (28)
Cape Point to Breede River	Red (R)	46 (5)
Breede River to Cape St. Francis	Green (G)	149 (15)
Cape St Francis to Cape Padrone	White (W)	34 (3)
East of Cape Padrone	Black (K)	10 (1)
East coast	Turquoise (T)	9 (1)

Aerial surveys

To locate oystercatcher high-tide roosts north of Elands Bay, South Africa, aerial surveys were conducted from 4 to 7 May 2004 from Elands Bay to Lüderitz, Namibia, and from 28 to 30 August 2004 from Lüderitz along the Skeleton Coast to the Cunene River on the border between Namibia and Angola (Figure 2.1). Roosts south of Elands Bay were considered to be well known, so the area was not surveyed from the air. Aerial surveys were preferable to ground surveys due to the distances involved and the inaccessibility of much of the terrain north of Elands Bay. Also, the surveys could only be conducted over a 3-hour high-tide window during a spring tide cycle, in clear weather. A Cessna 172 4-seater high-wing plane was used for both surveys. Further details on survey planning are included in Appendix 1.

In addition to the pilot, one or two observers were aboard the plane. All were in communication through headsets. Each observer carried a set of 1:50 000 topographical maps of the coast, with latitude and longitude marked on the map. One observer, the spotter, was primarily responsible for locating the birds. The other observer, the navigator, carried a portable geographical positioning satellite (GPS) unit and was primarily responsible for following the plane's position on the maps, and noting on the map the area and coordinates where the spotter saw the birds (latitude, to minutes and decimals). Data recorded included location of the birds (by highlighting the general area on the map), a count of the number of birds in the roost, and human land use or disturbance along the coast.

The birds took flight before the plane reached them, so observers had to look ahead of the plane to see them. The plane averaged an altitude of 61 m above ground, at a speed of 90 kt (180 km/hour). A slightly faster speed was maintained over open, sandy areas. The pilot followed the coastline, flying slightly offshore, and circled an area when a roost site was located to obtain photographs or to get a more accurate GPS fix. The pilot avoided islands, due to the presence of breeding seals and birds. Oystercatchers generally do not roost on islands, presumably due to a lack of predators. A flight altitude of at least 305 m was required at the Orange River mouth and the Atlas and Wolf Bays area in Namibia due to the presence of flamingos (*Phoenicopterus minor* and *P. ruber*) and seal (*Arctocephalus pusillus*) colonies, respectively. No oystercatcher roost exists at the Orange River mouth. Any roost at the Atlas and Wolf Bays would have been missed.

Ground-truthing roost sites

Roosts between Koeberg in the south and Port Nolloth in the north of South Africa were checked from February to July 2004 and February to June 2005. Data collected since 1999 by other researchers from roosts in Namibia also were used for the analyses (see e.g. Leseberg 2001).

It was not possible to ground-truth all roosts located during the aerial survey for reasons including physical inaccessibility, and inaccessibility of some areas in Namibia due to stringent mining company security procedures. Roosts were prioritized for checking (see Appendix 2, Table A1) based on the number of birds estimated from the air, and accessibility of the area. Prioritized roosts were checked one to three times in both 2004 and 2005.

Roosts were checked at spring high tides (tidal height of 1.6 m or more) to ensure that the maximal number of birds would be present. A data collection form was prepared (see Appendix 3) to record information on roost size and composition, including banded birds and band combinations, and bird behaviour. On most occasions, two observers visited each roost with binoculars and two Kowa TSN-821 telescopes, with 20-60x zoom lenses.

Observers approached roosts slowly in order to not flush the birds. Observers gauged the birds' level of comfort and found a balance between being far enough away that the birds would not take flight, and close enough to be able to read colour bands through the telescopes (50-100 m). Total number of birds was recorded first. To get the birds to stand such that bands became visible, each observer would take a turn walking slowly towards the roost, stopping when the birds became alert and stood up, allowing the other observer to record band colours and numbers.

The age, hatch year, origins and previous movements of birds at the different roosts that were ground-truthed were determined, based on band colour, and compared among roosts. Other than for Dassen Island, the precise banding location of birds (within the general banding region) could only be determined if the 3-digit code on the long plastic band could be read. Numbers of first- or second-year unbanded birds also were recorded. These can be identified by reddish-brown eyes with a narrow, burnt orange eye ring, greyish-pink legs and brownish bills (Hockey 1986).

Other data were collected upon completion of the roost count and identification of banded birds. Overall, the numbers of banded birds will always have been underestimates, first because in some roosts it was not always possible to see the legs of all birds, and second because with time the engraved rings become increasingly worn and difficult to read, in some cases only allowing determination of age and banding region. The areas around the roost sites also were checked for banded birds at low tide to determine whether the birds used the immediate area for foraging.

Data analysis

Databases on all banded and resighted birds had previously been set up and were maintained throughout the study. As of June 2005, 340 of approximately 990 banded birds had been resighted at least once.

To determine timing of the birds' movements, only those birds that could be identified to individual level (i.e. those on whose long plastic bands the number could be read) were included in the analysis. The decision to do this initially was made in order to avoid counting the same bird twice, then maintained for consistency.

For the purposes of this study, a dispersal endpoint roost was defined as the area surrounding the high tide roost at the end of one direction of a bird's trajectory. A dispersal stopover roost was defined as the area surrounding a high tide roost in the area used by birds as a resting and refuelling point in the course of their dispersal, i.e. a site between their departure point and their endpoint (Erni *et al.* 2002). A departure point was defined as the bird's natal site.

Hockey *et al.* (2003) assumed that birds that had been seen at local dispersal roosts (in that case less than 150 km from natal sites) between 6 months and 2 years from hatching did not migrate. Following observations of birds that left the vicinity of their natal sites for Namibia in their second year or later, a more conservative method was chosen: only those birds that were seen in at least two consecutive years at a particular endpoint were included in the analysis. This was interpreted as an indication that the birds did not continue further north. All birds seen at Namibian roosts were used in the analysis, as they are among the northernmost known endpoints of the birds' dispersal range. This more conservative method limits the sample size, however the results allowed for more rigorous confirmation of a bird's dispersal endpoint and the method reduced the chance of Type II error.

Based on the date of banding and the dates and locations resighted, year of dispersal, year of return and year of return to natal site were calculated for those birds recorded travelling to endpoints north of Elands Bay. Elands Bay is within the birds' main South African breeding range and therefore was considered to be the northernmost 'local dispersal roost'. Year of return is defined as the year in which a bird that had been resighted at a dispersal endpoint was later resighted further south. 'Natal site' was defined as the actual area (e.g. island) at which the bird was hatched. 'Endpoint' was defined as roosts at the northern limits of the known dispersal range (i.e. Namibian roosts), at which the bird was resighted, plus South African roosts at which a bird had been resighted in more than one consecutive year. A bird year was set as starting on December 1 of any given year for calculation purposes and because a new season of bird banding generally begins in December.

In most cases, it was not possible to determine the exact year of dispersal or return because many birds were not resighted in consecutive years; however, a range of years within which the dispersal or return took place could be determined. Although it is likely that dispersing birds would eventually return, birds that had not been seen to return following dispersal were not assumed to have returned or be returning. The number of birds shown to disperse in each year or range of years was counted. A cumulative distribution was used to graph the data. Year 1 refers to a hatch-year bird, i.e. a bird in its first year of life, year 2 refers to a bird in its second year of life, etc.

An index of body condition was measured as the ratio of body mass (grams) to tarsal length (millimetres) of chicks at the time of banding. Hatch date was calculated by estimating the age in days of a chick at the time of banding based on the relationship between tarsal length (mm, the most conservative growth parameter) and age documented by Hockey (1984; see Appendix 4). Relative hatch date of an individual was calculated as the number of days by which its hatch date followed the hatch date of the earliest-banded bird in any given breeding season. The use of relative hatch date, rather than actual hatch date, provided a means of comparing within years and controlling between years. Linear regression was used to compare each variable against distance travelled and dispersal endpoint. Distance travelled was calculated in kilometres from a bird's natal site to its dispersal endpoint using an existing database of relative shoreline positions, in kilometres, of points around the African coast (Oystercatcher Conservation Programme, unpublished data). Relative shoreline position was also used as a measure of the dispersal endpoint, when considered a response variable itself, to determine whether the use of a certain destination, rather than travelling distance, was determined by body condition or relative hatch date.

Age (bird years), hatch years and origin also were compared for birds seen at different roosts. Chi-squared analysis was used to determine whether observed proportions of resighted birds from different origins at confirmed endpoints reflected the proportions of birds banded at each origin, or indicated disproportionate representation from certain origins at certain endpoints. Data from observations at both high tide and low tide were included. Only presence/absence information is presented rather than numbers of birds of different ages and origins, because it was not possible to account for all birds present at all roosts, meaning that any count would be inaccurate. A significance level of $\alpha = 0.05$ was used for all analyses.

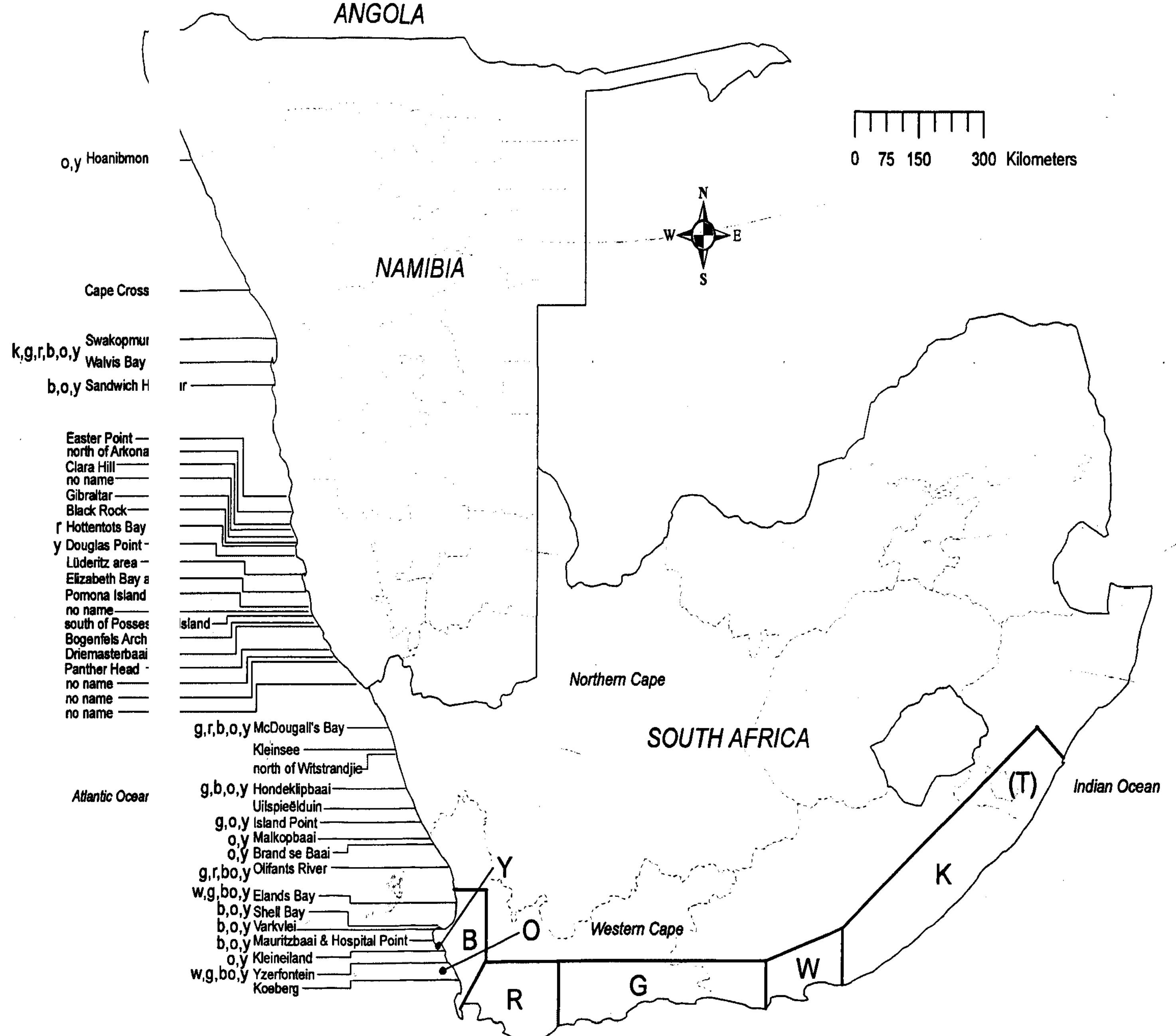

Figure 2.1. Locations and compositions of oystercatcher roosts on west coast s of South Africa and Namibia, and banding regions in South Africa. Banding regions (origins) are marked with capital letters; lower-case letters adjacent to roost site labels indicate origins of birds recorded at each roost site.

Results

Dispersal patterns

Destinations

From aerial surveys completed in May and August 2004 from Elands Bay, South Africa to the border between Namibia and Angola, roost sites were located along the entire South African and Namibian west coasts. Figure 2.1 shows the location of known roost sites along the western South African and Namibian coastlines, including previously known sites and those located in this study. Because there are no breeding records between Lüderitz and Möwe Bay in Namibia, it can be assumed that the birds at roosts north of Lüderitz were all non-breeding juveniles, immatures or subadults (Oystercatcher Conservation Programme, unpublished data).

A larger and more detailed map is contained in Supplement 1. Supplement 2 contains copies of 1:50000 topographical maps of the coastline showing the specific roost areas. Appendix 2 contains tables summarizing the locations of roost sites recorded during the aerial surveys.

Of the total number of individually marked birds (n = 106) whose dispersal endpoints were confirmed, 65% dispersed north of Lüderitz, Namibia, 11% dispersed to northwestern South Africa (Olifants River to Namibian border), 19% dispersed within southwestern South Africa (Cape Peninsula to Elands Bay), and 5% dispersed along the south coast (Figure 2.2). It is unknown how many dispersed to southern Namibia, as it was impossible, due to tight security, to visit the roost sites in the Namibian diamond mining area.

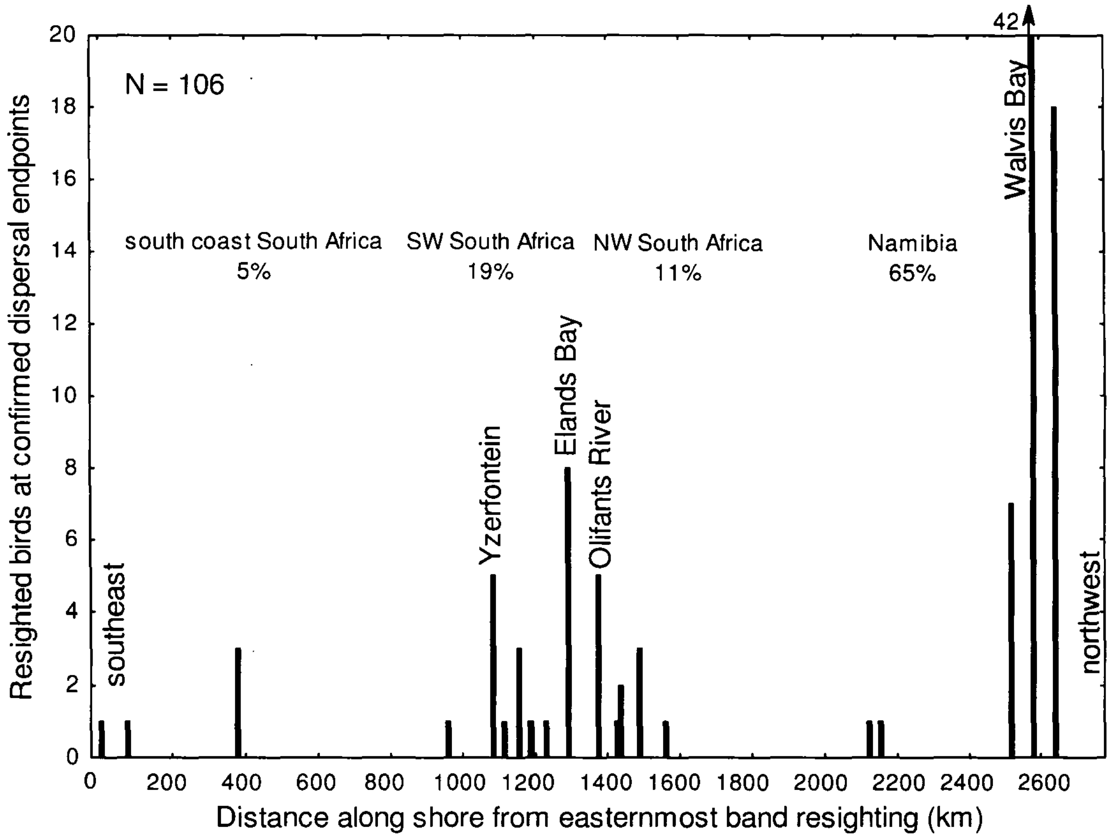

Figure 2.2. Number of resighted birds moving from their natal colony to confirmed endpoints

<u>Timing</u>

The results do not fully support the conclusion by Hockey *et al.* (2003) that all African Black Oystercatchers, particularly those travelling farther distances, travel away from the vicinity of their natal areas in their first year of life and return in their third or fourth year of life. Of those birds travelling north of Elands Bay, 22% definitely dispersed in their hatch year and 4% definitely dispersed later than their hatch year, in particular between years 2 and 5. It can therefore be concluded that the birds disperse while they are immature, but not necessarily while they are juveniles. Of those birds seen to have returned following dispersal, 25% definitely returned in their third or fourth year, whereas 9% definitely returned in their second year (Table 2.2). Most birds returned to their natal sites between years 2 and 4.

Uncertainties arose because not every bird was resighted in every year. Therefore, in many cases it was only possible to determine the range of years within which a bird moved in a particular direction. For example, bird A36 was banded in 1999 on Jutten Island (Saldanha Bay Islands banding region) and was resighted in its first year at Walvis Bay. It was not resighted again, however, until its third year (2001), at Shell Bay, one of the local dispersal roosts (i.e. in the vicinity of its natal site), then was resighted in its fourth year (2002) at its natal site. Although this resighting information proves that the bird returned to its natal site, it is not certain in which year it did so. It can only be concluded that it returned to the vicinity of its natal site between its first and third years and the natal site itself between its first and fourth years.

Given these uncertainties, of 139 birds observed to have travelled north of Elands Bay and 32 returning birds resighted, 73-99% dispersed in their first or second year and 9-87% returned between their second and fourth year. Figure 2.3 is a cumulative distribution graph summarizing the uncertainty ranges within which the observed dispersal patterns for all resighted birds fall. Each point represents the number of birds that dispersed by a given year. The solid points of each colour show the lower year estimate of the time range within which the bird travelled and the outlined points of each colour show the higher year estimate. "Reality" falls between the solid and outlined points of each colour, and can only be determined with more accuracy with additional years' data.

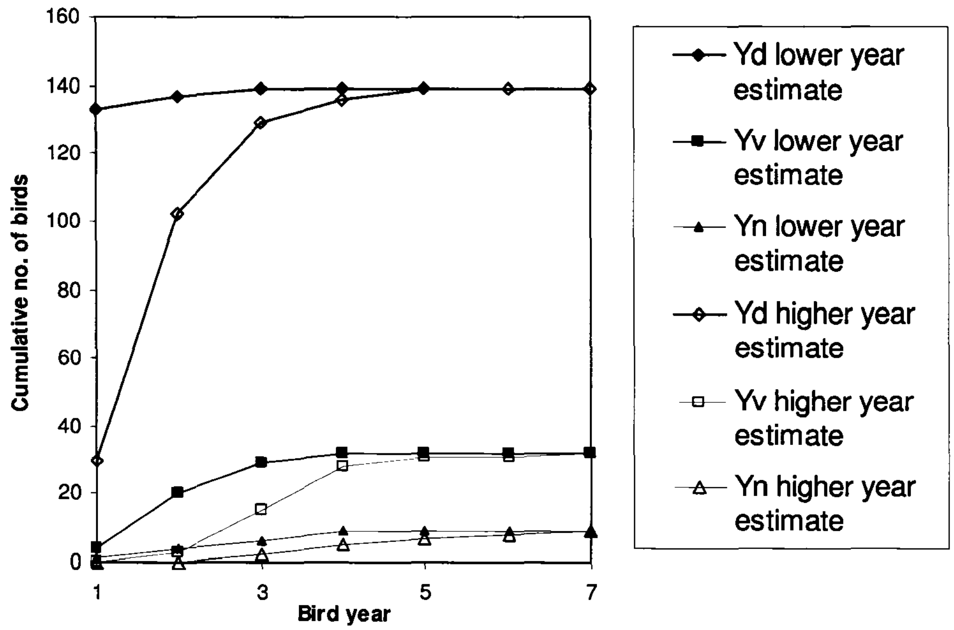

Figure 2.3. Cumulative distribution for timing of dispersal to endpoints north of Elands Bay, showing ranges of years in which dispersal and return took place for different individuals. Yd = year of dispersal; Yv = year of return to vicinity of natal site; Yn = year of return to natal site.

Table 2.2. Consistency of resighting observations with original hypotheses (percentages in parentheses)

Original hypothesis	No. observed to be consistent with hypothesis (percentage)	No. observed to maybe be consistent with hypothesis	No. observed to be inconsistent with hypothesis	Total
Year of dispersal = 1	30 (21.6)	103 (74.1)	6 (4.3)	139 (100)
Year of return = 3 or 4	8 (25.0)	21 (65.6)	3 (9.4)	32 (100)

Multi-purpose sites

It had been hypothesized that roosts north of Elands Bay and south of the Orange River were located in stopover areas for young birds travelling to or from dispersal endpoints in Namibia. First-year birds banded south of Elands Bay were resighted in 2004 and 2005 at Elands Bay, Olifants River, Brand se Baai and Malkopbaai, showing that these sites are used on northward dispersal. In addition, 10 individual birds were resighted in both

2004 and 2005 at Olifants River, Brand se Baai, Malkopbaai, Island Point and Hondeklipbaai, showing that these sites were dispersal endpoints for those birds. Five birds resighted between 2000 and 2003 at Namibian roosts were resighted at Brand se Baai, Olifants River and Malkopbaai roosts in 2004 and 2005, suggesting that these four are stopover sites for birds travelling southward.

These results indicate that a single roost site marks an area used by some immature oystercatchers as a northward or southward stopover site and by others as a dispersal endpoint. More importantly, they show that there are a series of dispersal endpoints along the entire South African west coast.

Furthermore, 50-100% of banded birds seen at high tide roosts were observed foraging in the immediate vicinity of the roost site at low tide at Elands Bay, Olifants River, Brand se Baai, Malkopbaai, Island Point and McDougall's Bay. This represents an underestimate, however, as it was impossible to see all birds present at low tide because of the shoreline topography.

Traditional sites

Roost sites at Elands Bay, Olifants River, Brand se Baai, Malkopbaai, Island Point, Hondeklipbaai and McDougall's Bay were used by oystercatchers in both 2004 and 2005. Local people had seen oystercatchers in some of these areas (Elands Bay, Olifants River, Brand se Baai, Island Point, Hondeklipbaai, Kleinsee, McDougall's Bay) in previous years, further confirming that they are traditional sites used year after year by the birds. Individual birds may use multiple roosts, however. For example, a banded bird seen at Malkopbaai in June 2004 was seen in February 2005 at Island Point; Malkopbaai contained no banded birds in February 2005 (although it did in June 2005), and the Island Point roost was larger in February 2005 than in June 2004. Movement of banded birds was also reported by Leseberg (2001) between Swakopmund and Walvis Bay and between Walvis Bay and Sandwich Harbour in Namibia.

Which birds travel further?

This study demonstrated that immature oystercatchers can disperse to a range of distances along the southern African coast, therefore it is more appropriate to consider distance travelled as a continuous variable rather than developing distance categories. To determine what could trigger birds to travel different distances, distance travelled (km) and dispersal endpoint (shoreline position in kilometres relative to a common reference point) was compared relative to several characteristics, as described in the Methods.

Linear regression analyses showed no significant relationship between maximal distance travelled (km) and body condition ($R^2_{1,98} = 0.001$, $p = 0.802$) or relative hatch date ($R^2_{1,99} = 0.002$, $p = 0.690$); or between dispersal endpoint and body condition ($R^2_{1,98} = 0.004$, $p = 0.523$) or relative hatch date ($R^2_{1,99} = 0.009$, $p = 0.334$). Sex also was not a factor determining maximal distance travelled, as blood sample analysis showed that 3 males and 2 females from South African natal sites travelled to roosts in Namibia ($N = 5$). Raw data are presented in Appendix 5.

Furthermore, immature birds of different ages, hatched in different years and from different origins did not use different roosts, but mixed along the dispersal route. Birds of more than one age class have been observed at all roosts, with the exception of Hoanib River, Douglas Point and Hottentots Bay, which were only visited on one occasion (only one banded bird was seen at the latter two sites), and Koeberg, at which no birds colour-banded through the Oystercatcher Conservation Programme had ever been seen (N. Parsons, University of Cape Town, *pers. comm.*). Table 2.3 summarizes the presence or absence of birds of different age classes at the various ground-truthed roost sites. To avoid the same bird being counted twice (i.e. if the same bird was at a roost site in two successive years), hatch years of birds at each site also were compared (Table 2.4). Birds hatched in different years were observed to roost together.

Birds from more than one origin were seen at all roosts ground-truthed more than once (Table 2.5, Figure 2.1). Banded birds from all origins were not seen at all ground-truthed roost sites. Birds from the Saldanha Bay Islands and Dassen Island (banding regions "Y" and "O" respectively) were seen at 15 of 17 and 14 of 17 sites, respectively. This could be because the banding effort is highest at these two areas (36% and 28% of all banded birds, respectively), and they represent significant breeding concentrations of oystercatchers. In order from northwest to southeast: birds from banding region "B" were seen at 10 of 17 roost sites; birds from banding region "R" were seen at 4 of 17 sites; birds from banding region "G" were seen at 7 of 17 sites; birds from banding region "W" were seen at 2 of 17 sites; and birds from banding region "K" were seen at 1 of 17 sites. This does not suggest a clear pattern regarding bird origin and distance travelled; birds from 6 of 7 origins, including the furthest east origin, were seen at Walvis Bay/Swakopmund.

There were no significant differences between the observed proportions of resighted birds of different origins (banding regions as per Table 2.1) at confirmed endpoints (divided into 4 regions as per Figure 2.2), given the proportions of birds banded at each origin (Namibia: $\chi^2 = 11.96$, df = 7, p = .10; NW South Africa: $\chi^2 = 2.63$, df = 7, p = .92; SW South Africa: $\chi^2 = 3.00$, df = 7, p = .89; south coast South Africa: $\chi^2 = 3.36$, df = 7, p = .85). In other words, the number of birds from each banding region seen at different endpoints reflects the relative numbers banded in each region.

Table 2.3. Ages of oystercatchers seen at ground-truthed roosts

Roost	**Bird Year** (1 = hatch year, etc.)							
	1	2	3	4	5	6	7	8
Koeberg								
Yzerfontein	✓	✓	✓	✓	✓	✓	✓	✓
Kleineiland	✓	✓	✓	✓	✓			
Mauritzbaai/ Hospital Point	✓	✓	✓	✓	✓	✓		
Shell Bay	✓	✓	✓	✓	✓	✓		
Varkvlei	✓	✓	✓	✓	✓			
Elands Bay	✓	✓	✓	✓	✓	✓		
Olifants River	✓	✓	✓	✓	✓	✓		
Brand se Baai	✓			✓				
Malkopbaai	✓		✓	✓	✓			
Island Point	✓	✓	✓	✓	✓			
Hondeklipbaai	(✓)*	✓	✓					
McDougall's Bay	(✓)*	✓	✓	✓				
Douglas Point				✓				
Hottentots Bay			✓					
Sandwich Harbour	✓	✓						
Walvis/Swakop	✓	✓	✓	✓				
Hoanib River	✓							

*These birds were either first- or second-year birds, unbanded but aged based on their colouring.

Table 2.4. Hatch year of oystercatchers seen at ground-truthed roosts

Roost	Hatch Year							
	pre-1998	1998-99	1999-2000	2000-01	2001-02	2002-03	2003-04	2004-05
Koeberg								
Yzerfontein	✓	✓	✓	✓	✓	✓	✓	✓
Kleineiland			✓	✓	✓	✓		
Mauritzbaai/ Hospital Point		✓	✓	✓	✓	✓	✓	✓
Shell Bay		✓	✓	✓	✓	✓	✓	✓
Varkvlei		✓	✓	✓				
Elands Bay		✓	✓	✓	✓	✓	✓	
Olifants River			✓	✓	✓	✓	✓	
Brand se Baai					✓		✓	
Malkopbaai			✓	✓	✓	✓		
Island Point			✓			✓	✓	
Hondeklipbaai					✓	✓	✓	
McDougall's Bay				✓	✓	✓	✓	
Douglas Point		✓						
Hottentots Bay			✓					
Sandwich Harbour			✓	✓	✓			
Walvis/Swakop		✓	✓	✓	✓			
Hoanib River			✓					

Table 2.5. Origins of oystercatchers seen at ground-truthed roosts (for more detailed breakdown, see Appendix 6)

Roost	**Region of origin, northwest to southeast** (Banding region code)						
	Saldanha Bay islands (Y)	Dassen Island (O)	Lambert's Bay to Cape Point (B)	Cape Point to Breede River (R)	Breede River to Cape St. Francis (G)	Cape St. Francis to Cape Padrone (W)	East of Cape Padrone (K)
Koeberg							
Yzerfontein	✓	✓	✓		✓	✓	
Kleineiland	✓	✓					
Mauritzbaai/ Hospital Point	✓	✓	✓				
Shell Bay	✓	✓	✓				
Varkvlei	✓	✓	✓				
Elands Bay	✓	✓	✓		✓	✓	
Olifants River	✓	✓	✓	✓	✓		
Brand se Baai	✓	✓					
Malkopbaai	✓	✓					
Island Point	✓	✓			✓		
Hondeklipbaai	✓	✓	✓		✓		
McDougall's Bay	✓	✓	✓	✓	✓		
Douglas Point	✓						
Hottentots Bay				✓			
Sandwich Harbour	✓	✓	✓				
Walvis/Swakop	✓	✓	✓	✓	✓		✓
Hoanib River	✓	✓					

Discussion

The results supplement those presented by Hockey *et al.* (2003) with a more complete explanation of the dispersal pattern of the African Black Oystercatcher. My results suggest that the dispersal pattern of immature African Black Oystercatchers is not dichotomous (migration to Namibia or Angola versus local dispersal) as was originally hypothesized; rather, the pattern is more indicative of dispersal to a range of distances along the coast. The results also do not show a gradual decrease in numbers of birds travelling to areas further north. Several oystercatcher roost sites have been found along the Atlantic coasts of South Africa and Namibia, most of which are used by juvenile and immature birds and are dispersal endpoints in the case of some birds. Thus, young African Black Oystercatchers disperse from 4 to over 2000 km from their natal sites, to one of several endpoints along the South African or Namibian coasts. Most birds resighted thus far (65%) moved to endpoints in Namibia north of Lüderitz, but some (11%) remained at roost sites along the South African northwest coast (Figures 2.1, 2.2). These numbers may be skewed by the more intense resighting efforts in Namibia.

Some dispersal endpoints have been used by individual birds in different seasons (e.g. Malkopbaai and Island Point; and Walvis Bay and Swakopmund), but the roost sites are traditional, with immature birds recorded roosting there in two or more years. A single site can be used by some individuals as a staging site and by others as a dispersal endpoint. The sites are used by birds on both their departure from and return to their natal sites. Furthermore, the immediate vicinity of the roost sites serves as a foraging area for most birds at low tide.

The results also suggest that the timing of the birds' dispersal is more complex than was originally hypothesized. Not all birds depart in their first year, nor do all birds return to the vicinity of their natal areas in their third or fourth year.

The situation of uncertainty and data gaps in determining the timing of the dispersal pattern is a common obstacle in capture-mark-recapture studies (Pollock *et al.* 1990, Lebreton *et al.* 1992). With additional years' data collection, this dispersal pattern may be described in more detail (see Appendix 7 for possible future methodology).

Birds hatched in different years mixed at roost sites along the dispersal route. Therefore birds in different years did not choose different endpoints. Birds of different origins mixed at roost sites along the dispersal route, thus the loss of any particular area would not likely have any more effect on one breeding region than on another.

There was no indication why certain birds travelled further than others. Body condition, relative hatch date, and sex did not differ significantly for immature African Black Oystercatchers dispersing different distances. This begs the question whether travelling distance in immature African Black Oystercatchers is inherited. Some siblings have already been recorded at the same endpoint. Birds individually banded through the Oystercatcher Conservation Programme are now beginning to breed. The next generation of birds may follow their parents' dispersal patterns. If so, it remains to be seen whether it is a maternally- or paternally-inherited trait.

The immature oystercatchers' dispersal pattern in general may reflect existing ecological conditions, including intra-specific competition related to population density or changes in food availability. Its similarity to the movements of other oystercatchers provides some insight.

The behaviour of many immature African Black Oystercatchers of remaining at a 'wintering' site or endpoint for a few years prior to returning to their natal/breeding area is similar to patterns shown by the Eurasian Oystercatcher, *Haematopus ostralegus*. Young Eurasian Oystercatchers often linger close to or in their wintering area during their second to fourth summers, rather than returning to their breeding area. Reasons for this behaviour include the lack of advantage for young birds to migrate long distances back to the breeding region before they need to find a breeding territory, and the opportunity provided on the wintering grounds to forage without adult competition (Ericksson 1987). Oystercatchers and other waders require time to develop efficient foraging skills, therefore they can forage more successfully in their inefficient years if they do not need to compete with more proficient adults (Cadman 1980, Goss-Custard and dit Durell 1987, Hulscher *et al.* 1996, Hockey *et al.* 1998, Leseberg 2001). Furthermore, because oystercatchers have deferred sexual maturity (Hockey 1996a), there may be no advantage (and likely a disadvantage) for them to return to their breeding grounds before reaching breeding age. This is especially true if they are not experiencing energy stress on their non-breeding grounds (Leseberg 2001). It is not known how a migrating juvenile Eurasian Oystercatcher chooses a migration endpoint, although it has been hypothesized to be an inherited trait (Hulscher *et al.* 1996). Eurasian Oystercatchers differ from African Black Oystercatchers, however, in that a substantial proportion of the population remains migratory throughout their lives.

Spreading or expansion of populations can extend to their wintering areas, and can occur in residents, partial migrants, or true migrants (Berthold 2001). In the case of residents, it usually occurs because of an increase in population size; increased densities may lead to increased competition, pushing juveniles to distant areas to avoid this competition (Rappole 1995). In the early 1980s, the world population of *H. moquini* was about 4800 birds. Since then, numbers have increased to an unmeasured extent, but could be as high as 6000-7000 birds (Oystercatcher Conservation Programme unpublished data). This reflects increased densities of territorial adults within the species' breeding range. Although the immature oystercatcher roost at Walvis Bay has existed since the 19th Century (Gurney 1872), it may be predicted that the number of birds that disperse further distances is increasing as the species' population increases. It is unknown, however, whether the current increase represents a return to previous levels or a new expansion of the population, as the population's trajectory prior to the 1980s is unknown. Genetic research planned by the Oystercatcher Conservation Programme should help to answer this question.

Increased frequency of longer-distance dispersal also is predicted to be correlated with increases in prey availability, for example increased abundance of the Mediterranean mussel *Mytilus galloprovincialis*, which has become a dominant prey item for the African Black Oystercatcher throughout much of its range (Hockey and van Erkom Schurink 1992, Hockey 1996b). Researchers have already shown that increases of alien species such as *M. galloprovincialis* have led to increased overall intertidal mussel abundance and biomass along the South African and Namibian coasts (Branch and Steffani 2004, Robinson *et al.* 2005, E. Wieters, *pers. comm.*). Increased food availability may be leading to increased breeding success, followed by density-dependence forcing young birds to disperse further to avoid competition with adults. Decreases in human disturbance at breeding areas following protection measures also may be a factor influencing breeding success, and therefore dispersal distance.

In conclusion, sites along the entire west coast of South Africa, and presumably Namibia, are traditionally used by immature African Black Oystercatchers as stopover sites and dispersal endpoints. Birds leave their natal areas while they are immature, but not necessarily juvenile. Access to sites outside of the species' primary breeding areas, and therefore away from competition with adults for space and food, likely provides an advantage to immature birds. These findings emphasize the conservation importance of these sites.

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Chapter 3
Habitat Characteristics and Conservation along Dispersal Routes of the African Black Oystercatcher *Haematopus moquini*

Abstract:
*I examine the habitat characteristics of the roost sites of the African Black Oystercatcher (*Haematopus moquini*) along its post-fledging dispersal route along the west coasts of South Africa and Namibia. I also discuss current threats to the conservation of oystercatchers and other shorebirds on these coasts. Roost sites differ significantly from sites without roosts on the basis of various physical habitat characteristics; in particular roosts are located most often in wave-sheltered areas containing both rock and sand, less often containing only sand, and with a maximum visibility angle at ground level greater than 180° in more than 70% of cases. This being said, roost sites occur in a range of habitats, likely limited by the availability of ideal habitat, particularly at more northern latitudes. Maximum roost sizes are highest in sheltered areas close to river mouths. These findings suggest that although roosts are located in various habitats, these characteristics are the most important. Larger roost sizes also tend to be correlated with lower numbers of limpets, which represent one of the oystercatchers' prey items. Maximum roost size peaks in three distinct locations along the coastline that coincide with major shifts in habitat type. All but one roost checked also contained other shorebird or seabird species, showing that the roosts are important from a multi-species perspective. Several roost sites are located in areas zoned for development or diamond mining. Development has, in the past, resulted in the loss of at least one oystercatcher roost site. Diamond mining has caused major structural changes along the coast. Recommendations are made to minimize the impact of these activities on shorebirds, including minimizing ribbon development along the coast and diverting mining operations away from known roost sites.*

Key words: *African Black Oystercatcher, development, diamond mining, habitat conservation, juvenile dispersal, long-distance dispersal*

Introduction

Shorebird habitat conservation

Shorebird conservation requires a landscape-level approach, because shorebirds use several habitat types at different times and in different locations along migration and dispersal routes, including breeding, staging and wintering areas (Berthold 2001). The African Black Oystercatcher (*Haematopus moquini*) in southern Africa, for example, uses sandy or shelly beaches, rocky shores, offshore guano islands and mudflats at various times during its life cycle (Hockey 1983, Hockey 1985, Leseberg 2001).

Shorebirds exhibit high levels of inter-annual site fidelity to breeding, staging and wintering sites (Hayman *et al.* 1986, Rehfisch *et al.* 1996, Berthold 2001). Most migratory birds show a clear habitat preference as juveniles before their departure, often based on their morphology, method of locomotion and foraging behaviour (Leisler 1990, Berthold 1996). When habitat choices for a migrating bird are unfamiliar or different from the choices in the area from which they departed, the birds' choice could be based on an abstract, endogenously determined habitat preference (Berthold 2001).

Shorebirds' vulnerabilities include the fact that the nests of most species are shallow and the birds are easily disturbed, facilitating predation, trampling, drowning or starvation of eggs or young (Patterson *et al.* 1991, Leseberg *et al.* 2000, Plissner and Haig 2000, Hockey 2001). Shorebirds also have a tendency to congregate, particularly in the non-breeding season (Drake *et al.* 2001), in areas such as high-tide roost sites, and migration or dispersal stopover sites and endpoints (Thurston 1996). Thus, threats to these areas have the potential to influence a sub-population or even an entire population. Shorebirds may spend most of the year in non-breeding areas (Drake *et al.* 2001), highlighting the importance of the conservation of these areas.

Several human-induced factors could result in negative effects on dispersing and migratory shorebirds and their habitats, including habitat restriction following development, hunting, human harvesting of the birds' prey, sea-level rise following climate change, pollution, disturbances associated with tourism and recreation (Prater 1981, Evans and Dugan 1984, Hayman *et al.* 1986, Berthold 2001) and potential increases in predation following disturbances (Ydenberg *et al.* 2002).

The African Black Oystercatcher

The African Black Oystercatcher is listed as *Near-threatened* on the IUCN Red List of threatened species (BirdLife International 2004b). Globally, the species is considered rare, with a world population of 6000-7000, 75% of which are in South Africa (Oystercatcher Conservation Programme unpublished data).

The African Black Oystercatcher does not undertake regular, seasonal migration, but many young of the species undertake long-distance dispersal. Resightings of individually-marked colour-banded birds have shown that South African-bred birds disperse from their natal sites to a range of locations along the Atlantic coasts of South Africa, Namibia and southern Angola once while young and linger at dispersal endpoints for a few years before returning to their natal sites for the remainder of their lives (Hockey *et al.* 2003; Chapter 2). The sites between the extremes of the dispersal route may be used by birds both as staging sites and dispersal endpoints (Chapter 2). The dispersal route of young African Black Oystercatchers includes areas with low human population density, but diamond mining takes place along large sections of the coast.

Like other oystercatcher species, the African Black Oystercatcher forms communal roosts at high tide when immature or during the non-breeding season (Hockey 1996). Roosts tend to be small, relative to those of many other bird species, and seasonally variable in size. Roost-site fidelity is high. Roost-site features documented on the south and southwest coasts of South Africa suggest that roosts are adapted for predator avoidance. In particular, roosts are located primarily on sheltered rocky shores with promontories and good all-round visibility, and near rivers (Hockey 1985).

This chapter characterizes the habitat of African Black Oystercatcher roost sites identified in 2004 (Chapter 2) on the west coasts of South Africa and Namibia, and describes potential conservation threats at these sites. In particular, it compares physical and biotic features at sites used and not used by the birds as roosts. It also compares features at sites containing different numbers of oystercatchers. Finally, it compares the locations of known human activities along the coast with roost locations. If roost sites possess particular characteristics and are threatened, this is a concern for the species' conservation. If sites are randomly chosen, then the birds are opportunistic and may be able to adapt and move to less disturbed sites. While it is not possible at this stage to predict with certainty whether the loss of a roost site would increase oystercatcher mortality, it is possible to determine which habitat features may determine roost site selection, whether these are common features of the shoreline, how randomly roost sites are distributed along the coast and what steps can be taken to minimize the effects of human activities on roosting areas.

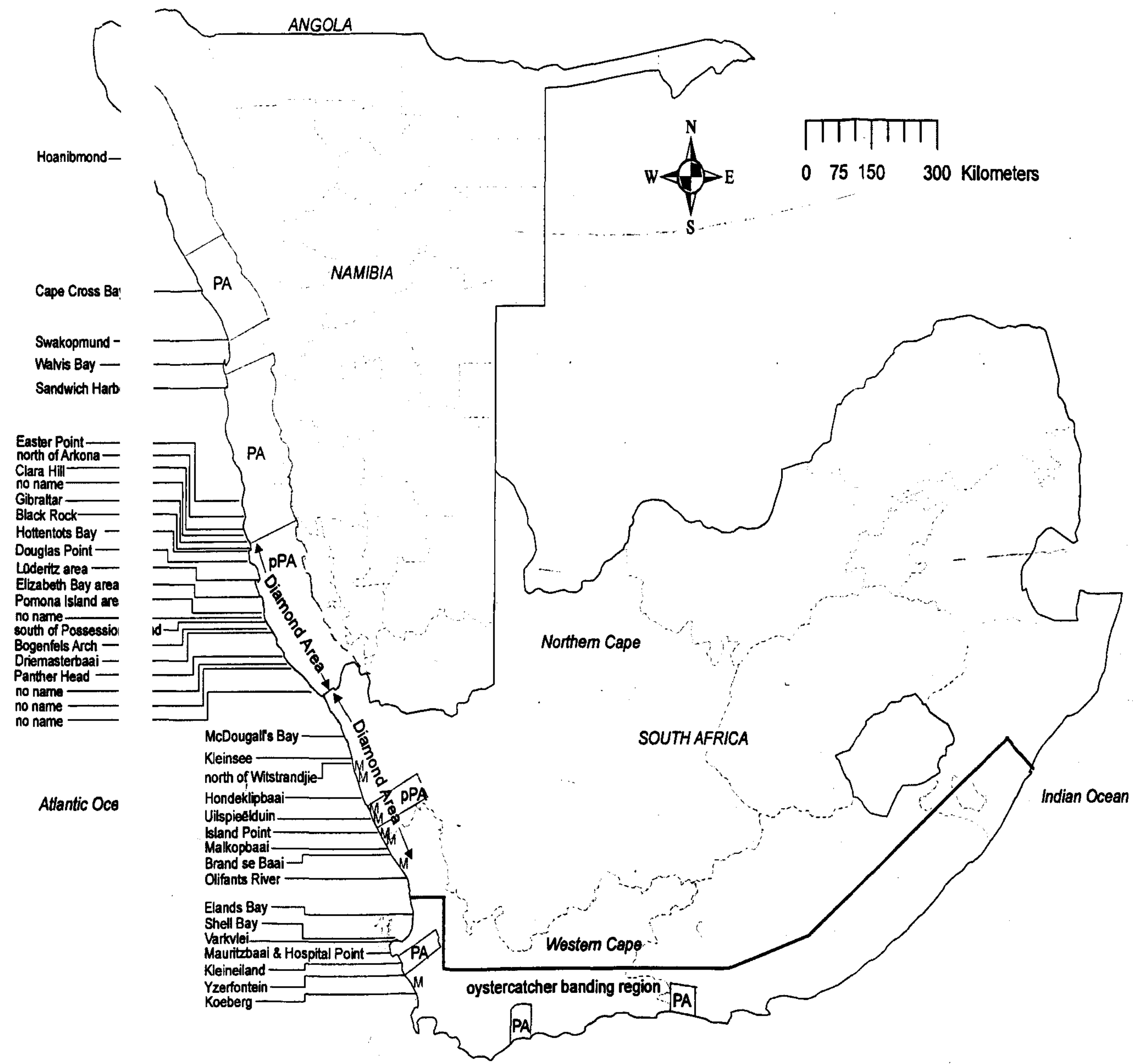


Figure 3.1. Locations of 40 African black oystercatcher high-tide roosts along the west coast of South Africa and Namibia, mollusc data collection locations, banding regions, diamond mining regions and protected areas. M = sites without roosts from where mollusc data were collected, PA = protected area, pPA = proposed protected area. Protected areas from NW to SE are: Skeleton Coast National Park, Nasionale Weskus Toeriste Ontspanningsgebied, Namib-Naukluft Park, Proposed Sperrgebiet Multi-use Zoned National Park, Proposed Namaqualand Marine Protected Area, West Coast National Park, De Hoop Nature Reserve, Tsitsikamma National Park. Marked inland boundaries of protected areas are not to scale.

Methods

Study area

Research was conducted on the west coasts of South Africa and Namibia from February to July 2004 and February to June 2005. Roosts checked ranged from Koeberg to Port Nolloth in South Africa (Figure 3.1), as well as Walvis Bay in Namibia. Historical data from roosts in Namibia also were used (Leseberg 2001, Oystercatcher Conservation Programme, unpublished data). Habitat data for Namibian roosts were obtained from 1:50 000 topographical maps for those sites not visited on the ground.

Aerial surveys

To locate oystercatcher high-tide roosts to the north of Elands Bay, South Africa, aerial surveys were conducted from 4-7 May 2004 from Elands Bay to Lüderitz, Namibia, and from 28-30 August 2004 from Lüderitz along the Skeleton Coast to the Cunene River, which forms the border between Namibia and Angola (Figure 3.1). Roosts south of Elands Bay were believed to be well known, so an aerial survey was not required. Aerial surveys were preferable to ground surveys due to the inaccessibility of much of the terrain north of Elands Bay, as well as the time limits of the tidal cycle. The surveys could only be conducted over a 3-hour high-tide window during a spring tide cycle, in clear weather. A Cessna 172 4-seater high-wing plane was used for both surveys. Further details on survey planning are included in Appendix 1.

In addition to the pilot, one or two observers were aboard the plane. All were in communication through headsets. Each observer carried a set of 1:50 000 topographical maps of the coast, with latitude and longitude marked on the map. One observer, the spotter, was primarily responsible for locating the birds. The other observer, the navigator, carried a portable geographical positioning satellite (GPS) unit and was primarily responsible for following the plane's position on the maps (essential in some of the more remote desert areas), and noting the area and coordinates on the map where the spotter saw the birds (latitude, to minutes and decimals). Data recorded included location of the birds (by highlighting the area on the map), a count of the number of birds in the roost, and human land use or disturbance.

The birds took flight before the plane reached them, so observers had to look ahead of the plane to see them. The plane averaged an altitude of 61 m above ground, at a speed of 90 kt (180 km/hour). A slightly faster speed was maintained over open, sandy areas. The pilot followed the coastline, flying slightly offshore, and circled an area when a roost site was located, in order to obtain photographs of the area or try to get a more accurate GPS fix of the roost. The pilot avoided islands, due to the presence of breeding seals and birds, including African Black Oystercatchers. Oystercatchers generally do not form large roosts on islands, presumably due to a lack of predators. A flight altitude of at least 305 m was required at the Orange River mouth and the Atlas and Wolf Bays area in Namibia due to the presence of flamingos (*Phoenicopterus minor* and *P. ruber*) and seal (*Arctocephalus pusillus*) colonies, respectively. No oystercatcher roost exists at the Orange River mouth (P.A.R. Hockey, *pers. obs.*). Any roost at Atlas and Wolf Bays would have been missed.

Ground-truthing roost sites

Roosts were checked at spring high tides (tidal height of 1.6 m or more) to ensure that the maximal number of birds would be present. A data collection form was prepared (Appendix 3) to record information on roost size and members, indicators of disturbance, and relevant habitat characteristics (following Hockey 1985).

It was not possible to ground-truth all roosts located during the aerial survey for reasons including physical inaccessibility of some areas, and inaccessibility of roosts in Namibia due to stringent mining company security procedures. Roosts were prioritized for ground-truthing (see Appendix 2, Table A1) based on the number of birds estimated from the air, and accessibility of the area. Prioritized roosts were checked one to three times in both 2004 and 2005.

A total of 12 roosts were ground-truthed; physical habitat characteristics were measured from maps for 27 additional roosts and 102 additional sites without roosts. Sites without roosts included sites at which mollusc data had been collected by Evie Wieters and George Branch of the Zoology Department, University of Cape Town, and a stratified random sample compiled by measuring physical habitat characteristics of a 2-minute block at every 10 minutes of latitude on 1:50000 topographical maps of the coastline, excluding those blocks which contained roosts (see Appendix 8 for raw data). Mollusc data were available from Wieters and Branch for 7 roost sites (5 in the case of mussel biomass – see below) and a range of sites without roosts (9 in the mid-intertidal zone, 8 in the high intertidal zone and 4 for mussel biomass – see below).

Total numbers of oystercatchers were counted at each roost site. The maximum number of birds observed at a roost site, from this study or recent historical data, was used as a measure of the site's potential importance to the species.

Physical variables measured or estimated from maps at roost sites and sites without roosts included exposure to wave action (coded as 0 for sheltered, 1 for semi-sheltered or 2 for exposed), presence of sand (coded as 0 for absence and 1 for presence), presence of rock (0 for absence and 1 for presence), the number of substrata (coded as 1 meaning either sand or rock, or 2 meaning both), the presence within one minute of latitude of a promontory (0 for absence and 1 for presence), the proximity of a river mouth (measured in kilometres) and the maximum angle of visibility from ground level in the area of the roost (estimated in degrees). Maximum visibility angle refers to the portion of a circle around the roost (ranging from 180 to 360°) at ground level that is covered by water; it amounts to the angle from which a terrestrial mammalian predator could not approach due to the presence of water. Proximity to the next nearest roost site and proximity to the nearest river mouth (perennial or ephemeral) were measured from 1:250 000 topographical maps. These physical variables were prioritized for analyses because they were relevant to oystercatcher roosts studied by Hockey (1985), easily measurable and comparable among sites along the entire coastline, even those sites that could not be accessed from the ground.

Biotic variables were based on data gathered by E. Wieters as part of a larger study examining alongshore variation in intertidal community structure. Biotic variables included in my study were percent cover of mussels *Mytilus galloprovincialis* and *Aulacomya ater* (pooled); number of limpets *Scutellastra granularis* per 0.25 m^2 quadrat; and biomass of *M. galloprovincialis*. These three molluscs are prey items for *H. moquini*.

Wieters conducted quantitative surveys of the 4 major tidal zones (lowest fringe, low, mid, upper) recognized at wave-exposed and wave-protected habitats at each site. Platforms were selected to be comparable in exposure to wave action. Percentage cover within a minimum of six 0.25 m^2 quadrats was sampled at haphazard intervals (1-5 m) along 20-50 m long transects stretched parallel to the shore in each zone. At most sites, 2-3 transects (30-100 m apart) per zone were sampled. Visual estimates of percentage cover were aided by a monofilament grid of twenty-five 10 x 10 cm squares (i.e. 4% cover each). To maintain accuracy for species of low cover (i.e. < 2%), presence of species covering less than 1% of quadrat area were noted and later given a mark of 0.5% cover. Covers of species inhabiting primary space (attached to the rock surface) and secondary space (atop other organisms) were estimated separately, therefore total cover could exceed 100%.

Biomass (wet weight) of *M. galloprovincialis* was calculated for each quadrat using area/mass regressions. To obtain site-specific conversion equations (> 5 % cover), a minimum of 5 samples was collected from each site. Patches of 100% primary cover were randomly selected and all material within a measured area was removed from the rock surface, rinsed, blotted dry, and weighed to the nearest 0.01 g. Mean mass per unit area was then multiplied by percentage cover to derive a biomass for the quadrat.

I used data from wave-exposed sites, as they best represented feeding areas, with the exception of Elands Bay, where oystercatchers had been observed foraging at wave-protected sites. Data from zones 3 (mid) and 4 (high) were used, as these zones are where the birds spend the most time feeding in wave-exposed areas, since they are relatively wide, tend to contain a relatively high amount of oystercatchers' main forage species (*M. galloprovincialis* and *S. granularis*) and are accessible during moderate swells (Oystercatcher Conservation Programme, unpublished data).

Conservation

The presence or absence of other bird species at roosts was recorded during roost ground-truthing visits. Conservation threats were examined through literature and resource map reviews, personal observation and discussions with officials from mining companies, the West Coast National Park, Marine and Coastal Management (Department of Environmental Affairs and Tourism), the University of Cape Town, the Wildlife and Environment Society of South Africa, and the Saldanha Municipality.

Data analysis

The majority of the habitat variables tested were not normally distributed, therefore the significance of differences in habitat characteristics between roost sites and sites without roosts was tested using chi-squared tests for categorical variables and Mann-Whitney nonparametric tests for continuous variables. Gamma regression was used to determine whether maximum observed roost size differed significantly given different habitat characteristics (analysis of residual plots showed that neither a normal error nor a Poisson error model would be appropriate, instead the data fit a gamma distribution). A significance level of $\alpha = 0.05$ was used for all analyses.

Results

Roost sites vs. sites without roosts

Hockey (1985) found that roosts on the southern and southwestern coasts of South Africa were located on sheltered rocky shores with promontories and good all-round visibility, and near rivers. It was observed that along the west coast of South Africa, oystercatchers foraged at low tide in the same general areas in which they roosted at high tide (Chapter 2). This suggested that food availability (measured as mussel and limpet abundance) in the vicinity also may be a key determinant for the location of roost sites. It was hypothesized therefore that roost sites would differ from randomly selected sites without roosts on the basis of all these habitat characteristics. Most variables were not inter-correlated (Appendix 9a).

Roost sites differed significantly from sites without roosts in the case of five physical variables (maximum visibility angle, exposure, number of substrata, presence of sand and presence of rock). No biotic variables differed significantly between roost sites and sites without roosts (Tables 3.1, 3.2). In particular, relative to sites without roosts, roosts were located more often in sheltered areas ($\chi^2 = 79.5$, df = 1, $p < 0.01$) containing both substrata ($\chi^2 = 40.5$, df = 1, $p < 0.01$), less often containing only sand ($\chi^2 = 33.0$, df = 1, $p < 0.01$), and with a maximum angle of visibility greater than 180° in more than 70% of cases (U = 1100.5, $p < 0.01$; see Figures 3.2 (a) through (c)).

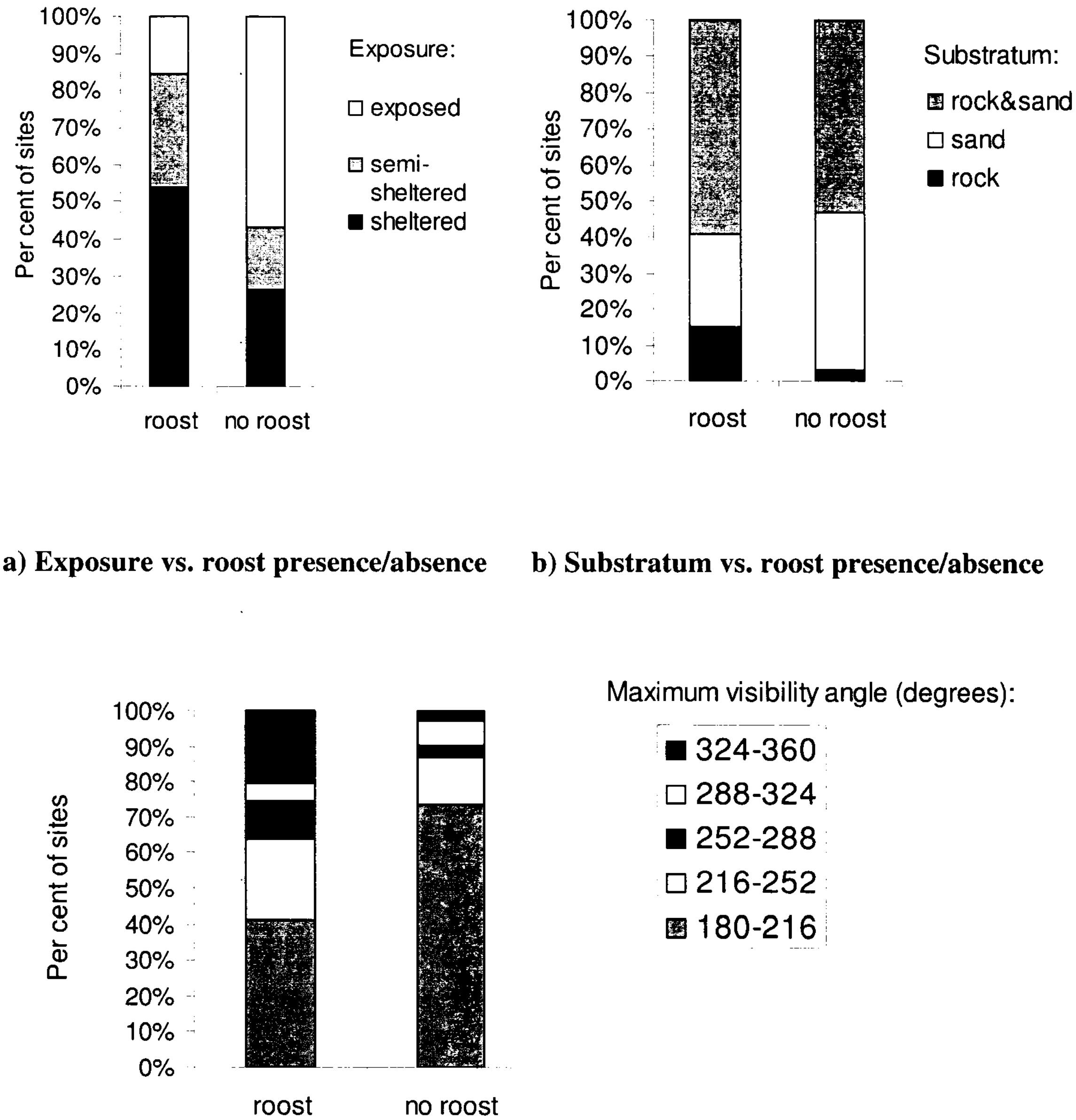
Table 3.1. Results of chi-squared analyses of categorical habitat variables: roost sites (r) and sites without roosts (nr) differed significantly with respect to most categorical habitat variables tested

Variable	Direction of difference	χ^2	DF	p
Exposure	r < nr	79.5	1	<0.01
# of substrata	r > nr	40.5	1	<0.01
Sand	r < nr	33.0	1	<0.01
Rock	r > nr	9.2	1	<0.01
Presence of promontory	r > nr	0.8	1	0.37

Table 3.2. Results of Mann-Whitney analyses of continuous habitat variables: roost sites and sites without roosts did not differ significantly with respect to most continuous habitat variables tested

Variable	Roost – Mean ± SD (N)	No roost – Mean ± SD (N)	U	P
Maximum visibility angle (^{o})	248.5 ± 64.8 (39)	205.5 ± 44.8 (102)	1100.5	<0.01
M. galloprovincialis biomass	1.4 ± 1.6 (5)	1.3 ± 2.0 (4)	7.0	0.46
No. of *S. granularis* (zone 3)	52.2 ± 44.8 (7)	59.7 ± 34.0 (9)	26.0	0.56
No. of *S. granularis* (zone 4)	37.1 ± 19.8 (7)	53.8 ± 41.8 (8)	23.0	0.56
Per cent cover mussels (zone 4)	1.4 ± 1.6 (7)	1.3 ± 1.9 (8)	22.5	0.60
Per cent cover mussels (zone 3)	53.5 ± 26.0 (7)	52.3 ± 31.3 (9)	30.0	0.87
Proximity of river (km)	43.1 ± 43.8 (39)	49.7 ± 61.7 (102)	1980.5	0.97

Figure 3.2. Habitat characteristics at roost sites and sites without roosts, for those variables that showed significant differences



a) Exposure vs. roost presence/absence

b) Substratum vs. roost presence/absence

c) Maximum visibility angle vs. roost presence/absence

Roost size

Roost sites along the western South African and Namibian coasts did not show homogeneous habitat characteristics. This makes it difficult to determine conclusively what constitutes 'suitable habitat' for an oystercatcher high tide roost, as a range of habitats is suitable. It was therefore tested whether maximum roost sizes were highest at sites with certain habitat characteristics.

Gamma regressions were run iteratively three times because of differing sample sizes available for different variables. The first analysis (N = 39) examined variance in maximum roost size given the various physical habitat variables, namely distance to the nearest roost, maximum visibility angle at the roost, exposure to wave action, proximity of a river mouth and presence of sand or rock. Maximum observed roost size varied significantly as a result of exposure to wave action – with sheltered sites being favoured (Wald stat = 12.58, df = 2, $p = 0.002$), and proximity to a river mouth (Wald stat = 10.41, df = 1, $p = 0.001$).

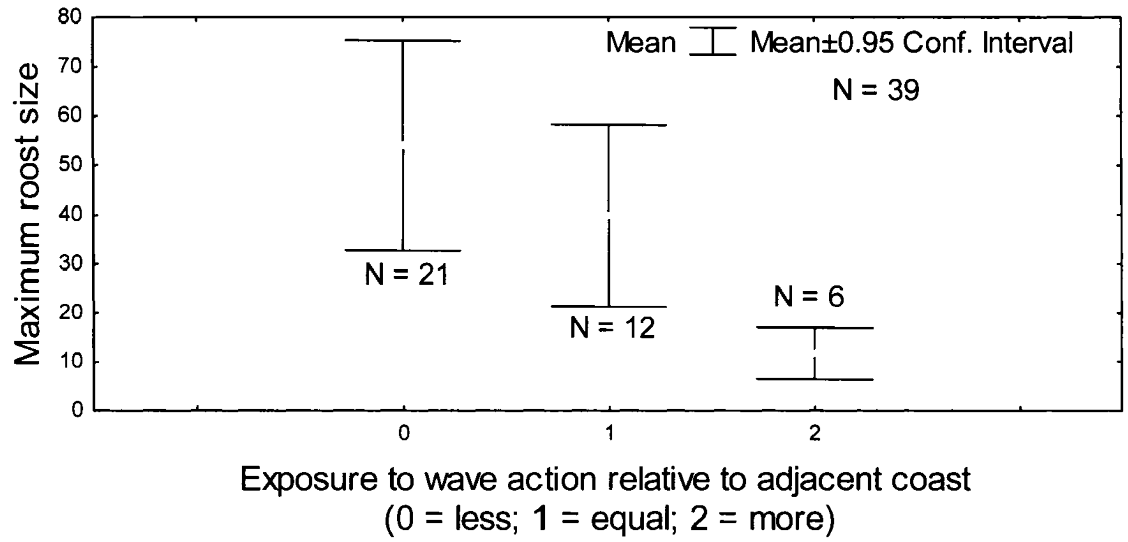
The second analysis (N = 7) examined variance in maximum roost size given exposure to wave action, proximity of a river mouth, percent cover of mussels in intertidal zone 3, and number of limpets (*S. granularis*) in intertidal zone 4 (the number of variables used had to be limited due to the small sample size, therefore those predicted to show the greatest effect were used). Exposure to wave action (Wald stat = 25.40, df = 2, $p < 0.001$), proximity to a river mouth (Wald stat = 15.36, df = 1, $p < 0.001$) and number of limpets – with maximum roost sizes being inversely related to limpet density (Wald stat = 42.89, df = 1, $p < 0.001$), were significant. However, the possibility of a type II error is high in this analysis, given the small sample size.

The third analysis (N = 7) examined variance in maximum roost size given exposure to wave action, proximity of a river mouth, and number of limpets (*S.*

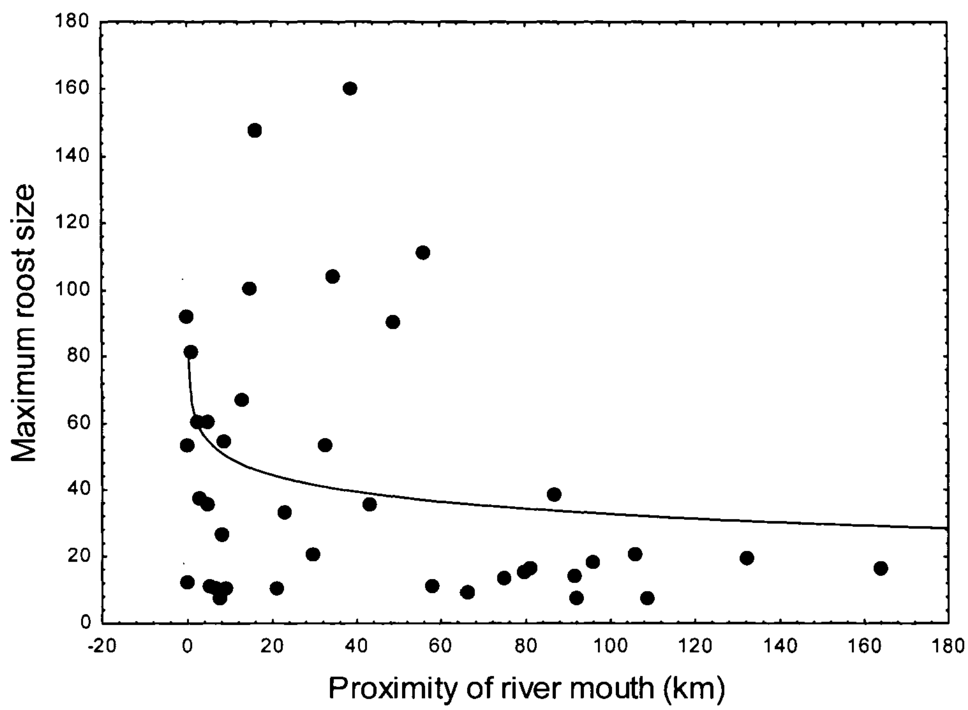
granularis) in intertidal zones 3 and 4. Exposure to wave action (Wald stat = 183.53, df = 2, $p < 0.001$), proximity to a river mouth (Wald stat = 6.61, df = 1, $p = 0.010$) and number of limpets in both zones (zone 3: Wald stat = 42.97, df = 1, $p < 0.001$; zone 4: Wald stat = 24.52, df = 1, $p < 0.001$) all showed a significant influence on maximum observed oystercatcher roost sizes, with the same relationships as outlined above.

Thus, higher maximum roost sizes occur in sheltered areas and mostly within 40 km of a river mouth (Figure 3.3 (a) and (b)), although given the short distances oystercatchers were observed to travel from their roost sites to forage, it is unlikely that a river mouth more than a few kilometres away would directly influence the site or size of a roost. Lower numbers of *S. granularis* were observed at larger roosts (Figure 3.3 (c) and (d)). Residual plots for all gamma regression analyses are presented in Appendix 9b.

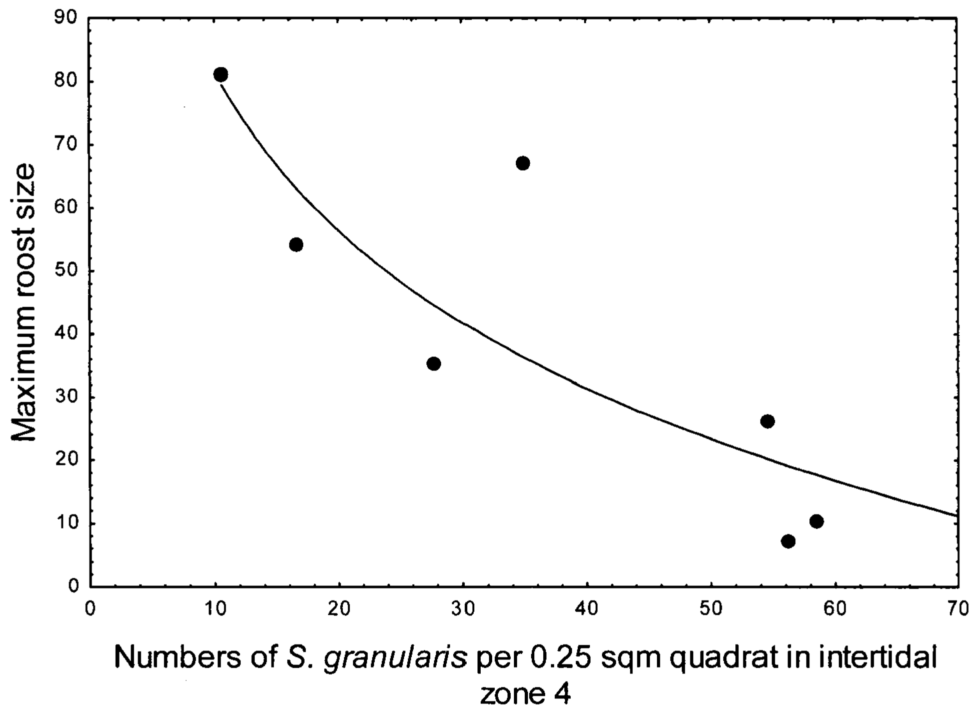
Figure 3.3. Habitat characteristics at roost sites for those variables that showed significant differences based on maximum observed roost size



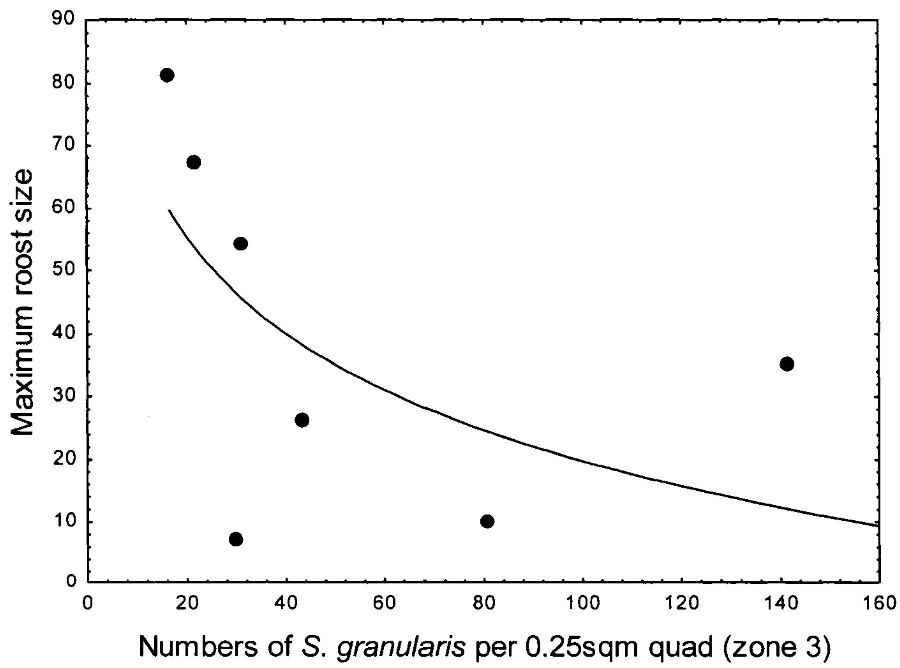
a) Maximum roost size vs. exposure to wave action



b) Maximum roost size vs. proximity to river mouth (km)



c) Maximum roost size vs. numbers of *S. granularis* in the high intertidal zone (zone 4)



d) Maximum roost size vs. numbers of *S. granularis* in the mid intertidal (zone 3)

Table 3.3. Species[1] richness at each oystercatcher roost[2] (non-exhaustive)

Avian species	Oystercatcher roost [2]													
	Ko	**Yz**	**Kl**	**Mh**	**Sh**	**Va**	**El**	**Ol**	**Br**	**Ma**	**Is**	**Ho**	**Ks**	**Mc**	**Total**
Kelp Gull		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	12
Hartlaub's Gull		✓	✓	✓		✓	✓	✓				✓		✓	8
Common Tern				✓				✓							2
Swift Tern		✓		✓	✓	✓	✓	✓			✓			✓	8
Sandwich Tern				✓		✓		✓			✓	✓	✓		6
Antarctic Tern								✓							1
Caspian Tern								✓							1
Bank Cormorant		✓													1
White-breasted Cormorant		✓		✓	✓		✓	✓	✓	✓	✓	✓		✓	10
Cape Cormorant		✓	✓		✓							✓			4
Crowned Cormorant		✓		✓				✓			✓			✓	5
Curlew Sandpiper						✓	✓					✓		✓	4
Eurasian Curlew								✓							1
Great White Pelican						✓									1
Little Egret				✓		✓		✓		✓	✓			✓	6
Heron sp.				✓		✓									2
Grey Plover					✓	✓		✓		✓					4
Blacksmith Lapwing				✓											1
Kittlitz's Plover				✓											1
White-fronted Plover		✓	✓	✓	✓	✓					✓			✓	7
Three-banded Plover		✓													1
Common Greenshank						✓									1
Ruddy Turnstone		✓		✓		✓				✓	✓	✓		✓	7
Sacred Ibis				✓		✓	✓								3
Glossy Ibis							✓								1
Speckled Pigeon		✓													1
Long-billed Pipit												✓			1
Black-winged Stilt							✓								1
Cape Wagtail							✓					✓			2
Sanderling							✓	✓		✓		✓		✓	5
Common Whimbrel								✓							1
Eurasian Oystercatcher										✓					1
South African Shelduck													✓	✓	2
Species richness	0	11	4	14	6	13	10	14	2	7	8	9	3	11	

Notes from Table 3.3:

[1] Scientific names in order, from top to bottom: *Larus dominicanus, Larus hartlaubii, Sterna hirundo, Sterna bergii, Sterna sandvicensis, Sterna vittata, Sterna caspia, Phalacrocorax neglectus, Phalacrocorax lucidus, Phalacrocorax capensis, Phalacrocorax coronatus, Calidris ferruginea, Numenius arquata, Pelecanus onocrotalus, Egretta garzetta,* Heron species not determined, *Pluvialis squatarola, Vanellus armatus, Charadrius pecuarius, Charadrius marginatus, Charadrius tricollaris, Tringa nebularia, Arenaria interpres, Threskiornis aethiopicus, Plegadis falcinellus, Columba guinea, Anthus similes, Himantopus himantopus, Motacilla capensis, Calidris alba, Numenius phaeopus, Haematopus ostralegus, Tadorna cana*

[2] Abbreviations used for oystercatcher roost sites: Ko = Koeberg, Yz = Yzerfontein, Kl = Kleineiland, Mh = Mauritzbaai and Hospital Point, Sh = Shell Bay, Va = Varkvlei, El = Elands Bay, Ol = Olifants River, Br = Brand se Baai, Ma = Malkopbaai, Is = Island Point, Ho = Hondeklipbaai, Ks = Kleinsee, Mc = McDougall's Bay

Conservation

Between two and 14 other shorebird and seabird species were present at all but one of the oystercatcher roost sites visited, with 33 different species recorded altogether (Table 3.3). The only oystercatcher roost site at which no other birds were seen roosting was at the Koeberg nuclear power plant.

Ten roosts are located in the Namibian diamond mining area, two of which are likely in active mining zones (F. Olivier, NAMDEB, *pers. comm.*), and eight roosts are located in active or potential South African mining areas (Figure 3.4). Four roosts in South Africa are currently in areas where coastal development is scheduled to increase, and at or in the vicinity of three roosts in South Africa, off-road vehicle use has been observed. The areas scheduled for coastal development largely possess the same physical attributes as the majority of oystercatcher (and other coastal birds') roost sites (Table 3.4, Chapter 4): wave-sheltered areas with both sandy and rocky shores and a maximum visibility angle greater than 180°. They are also located in areas relatively close to ephemeral or permanent river mouths, as are the largest oystercatcher roosts.

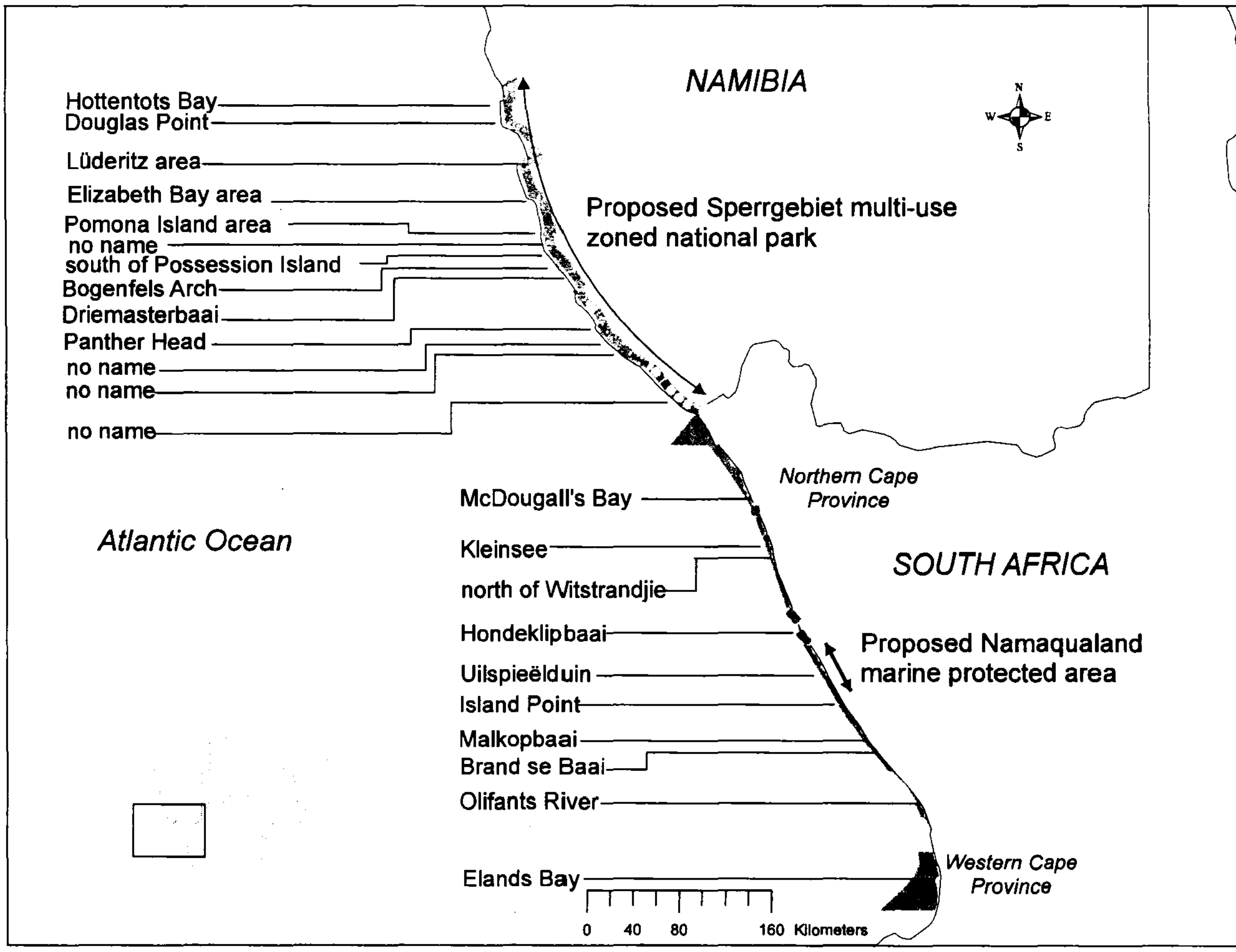


Figure 3.4. Location of active and potential diamond mining sites relative to west coast oystercatcher roosts and proposed coastal protected areas. Grey shaded areas along coasts indicate mining concession locations.

Table 3.4. Habitat characteristics at human developments in southwestern South Africa (based on Saldanha Bay Municipality 2000)

Development	Coastal use	Presence of roost yes (y) / no (n)	Wave exposure: 0 = sheltered; 1 = semi-sheltered; 2 = exposed	Sand	Rock	Maximum visibility angle (degrees)	Proximity of river mouth (km)
Velddrif	high-income residential	n	2	1	0	180	0
Slippers Bay	high-income residential	n	0	1	1	180	9
Sandy Bay	high-income residential, light industry, smallholdings, road	n	0	1	1	315	15
Britannia Bay/ Shell Bay	high-income residential	y	0	1	1	315	23
Paternoster	urban conservation	y (since moved)	0	1	1	337	0
Treskoskraal & environs	medium-income residential, industry?, road	y	0	1	1	315	19
Jacobsbaai & environs	high-income residential	y	0	1	1	337	32
Saldanha	military, light industry, shipping, oil storage, high-income residential, transport	n	0	1	1	300	3
Langebaan/ Mykonos	high-income residential	n	0	1	0	200	0
Summary	**7/9 high-income residential**	**4/9 have or had roosts**	**8/9 in wave-sheltered areas**	**9/9 sand**	**7/9 rock**	**Mean 275°**	**Mean 11.22 km**

Discussion

Habitat characteristics

Roost sites along the oystercatchers' dispersal route differ from sites without roosts in that they are located more frequently (but not exclusively) in sheltered areas more often containing both rock and sand, less often containing only sand, and having a maximum visibility angle exceeding 180° in more than 70% of cases. Areas sheltered from waves permit the birds to rest and preen while roosting and watch for predators rather than watch for waves. High angles of visibility also allow for more effective vigilance against predators. Rocky areas represent locations that contain food at low tide. The presence of both rocky and sandy habitat could allow for closer proximity to feeding areas both in the rocky intertidal zone and on wash-up.

Unlike south coast roosts studied by Hockey (1985), the majority of west coast roost sites are not located near rivers, which are much less common along the west coast of South Africa and Namibia. Roost sites, as compared to sites without roosts, also were not associated with high or low prey abundance. This might be explained by the high variability of mollusc levels along the coast, or by small populations of oystercatchers and other efficient predators on the mainland. Mainland limpet populations may be controlled by primary productivity and may therefore be limited by lower nutrient levels, rather than by predation (Bosman and Hockey 1988, Hockey and Bosman 1988, E. Wieters, *pers. comm.*). Mussel numbers may be controlled more by competition between mussels rather than by predation (Griffiths and Hockey 1987).

The largest maximum roost sizes occur in wave-sheltered areas close to river mouths. Roost sites located at river mouths allow for wider visibility angles, and therefore greater vigilance against predators. Areas containing the largest maximum roost sizes also typically have relatively low numbers of the limpet *S. granularis*. This is consistent with the findings of Hockey and Bosman (1988) that oystercatcher density tends to be inversely correlated with limpet prey density, particularly where oystercatchers are abundant. Other coastal and marine research has shown similar relationships between predator and prey numbers, for example cormorants

(*Phalacrocorax auritus*) and fish (Birt *et al.* 1987), and common periwinkle (*Littorina littorea*) and seaweed (Lubchenko 1978).

Therefore, although roosts are located in a variety of habitats, African Black Oystercatchers appear to congregate in the largest numbers at sites with a defined suite of characteristics. This suggests the following possibilities:

- The combination of those physical characteristics which show a significant relationship with maximum roost size represent ideal habitats, however the oystercatchers will at times use sites that are non-ideal;
- Those characteristics, along with adjacent food availability, occur together only in a limited number of sites along the coast, and are particularly sparse in the northern portion of the study area, therefore oystercatchers are compelled to aggregate in those areas in large numbers.

Ground observations along the coast between the Elands Bay and Olifants River roosts, in addition to the aerial surveys covering the entire coastline, suggest that not all physically 'ideal habitats' (as defined above) contain oystercatcher roosts. Furthermore, the majority of these 'ideal' sites also did not contain any other bird species. Thus, there may be additional factors, perhaps physical space available for roosting, the presence of other birds for added vigilance against mammalian predators, presence of nearby food sources, or limited human use of adjacent areas, that also determine the location of a roost site. An alternative explanation is that all physically suitable locations are not saturated, and that there is room for the oystercatcher population to expand to additional locations as it grows. At this point, however, this remains speculation.

The location of roosts in a variety of habitats likely indicates that the birds must be more opportunistic when they are limited by the availability of ideal habitat, particularly at more northern latitudes, where some roosts are in open, sandy areas. At the same time, roosts become sparser and larger as suitable habitat becomes sparser, in particular north of 26°S latitude, as shown in Figure 3.5. This figure also shows that the relationship between maximum roost size and latitude is not linear, but has three distinct peaks. This suggests that there are certain key aggregating points along the coastline for roosts. The southernmost peak represents roosts in close proximity to or slightly north of key breeding areas in South Africa such as the Saldanha Bay islands and Dassen Island, the peak around Lüderitz represents roosts in close proximity to key breeding sites on offshore islands in that area, and the peak further north in Namibia represents the dispersal endpoints of Sandwich Harbour, Walvis Bay and Swakopmund.

The density of roosts is highest at southern latitudes (between 35°S and 30°S) where, based on the analysis of roost sites and the stratified random sample of sites without roosts, there were a greater number of sheltered areas, more rivers, promontories, rocky or rocky and sandy substrata, and angles of visibility that are more often greater than 180°, signifying a convoluted coastline (Figure 3.5). There are fewer, but larger roosts between 30°S and 26°S, where the coastline lacks promontories and there are fewer rivers. Roosts are even more infrequent in the northern latitudes, particularly in the area between 26°S and 23°S, where the coast is largely exposed, with many open sandy areas, few promontories, and generally maximum visibility angles of 180° (i.e. a straight coastline). There are very few roosts north of 23° S, but those that exist are relatively large and contain only juveniles, immatures and sub-adults (Leseberg 2001). Maximum roost size showed no significant relationship with latitude or the distance to the nearest roost, likely explained by the largest roosts (at more northerly latitudes) being sparse.

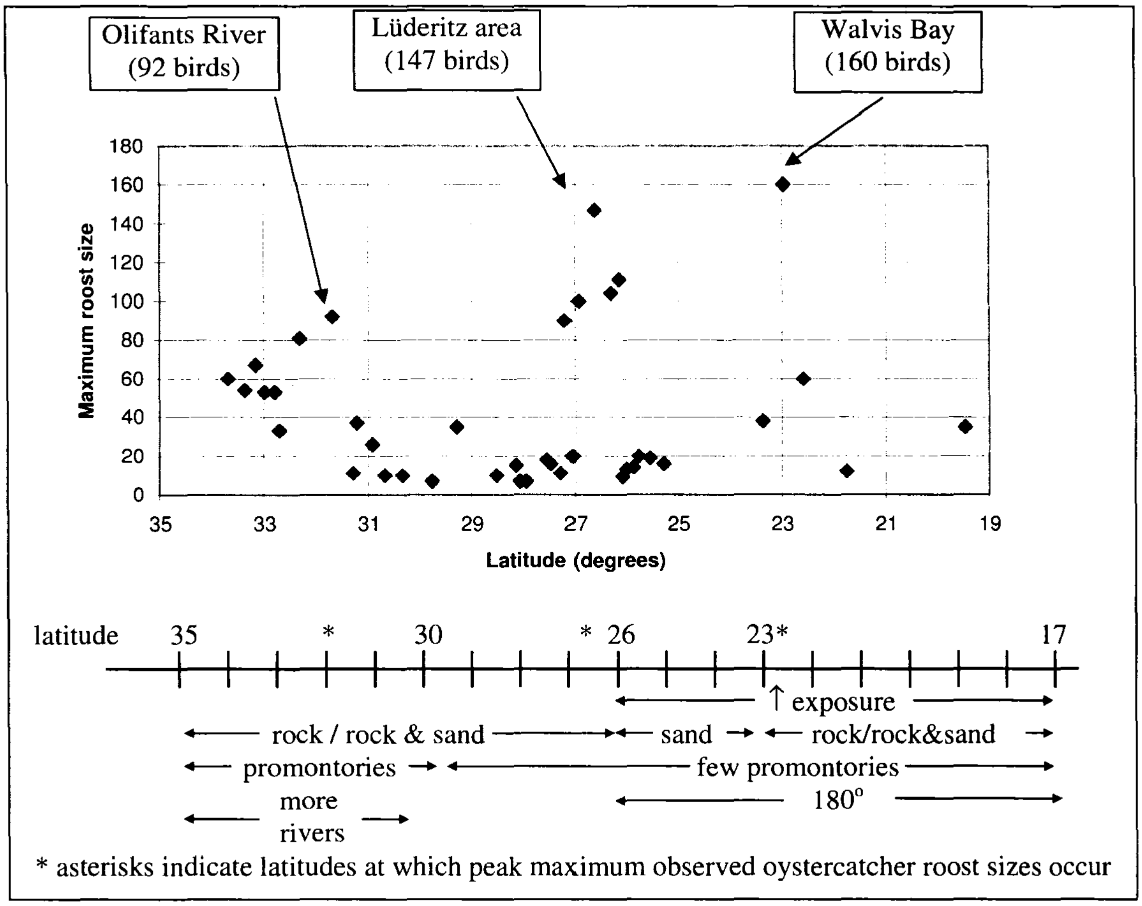


Figure 3.5. Maximum roost size and physical habitat zones in relation to latitude

Oystercatchers around the world have varying roosting habitat requirements, but key factors include predator avoidance, shelter and prey location, as was found in the case of the African Black Oystercatcher. Magellanic Oystercatchers (*Haematopus leucopodus*) roost at high tide on sandy or rocky shores in an orientation that allows them to avoid wave action, and forage largely on mudflats that become exposed during the ebbing tide (Siegel-Causey 1991). Eurasian Oystercatchers (*H. ostralegus*) aggregate at traditional sites containing local concentrations of their prey (Ens and Cayford 1996). Their foraging locations depend on a combination of prey location, risk of predation and the proximity of a high-tide roost, rather than on food abundance alone (Goss-Custard *et al.* 1996).

Conservation

There are many reasons why roost sites represent important areas for conservation, not least that they tend to be traditional for many shorebirds (Hayman *et al.* 1986, Berthold 2001), including the African Black Oystercatcher (Chapter 2). As mentioned previously, high-tide roosts contain significant proportions of a population, particularly of an uncommon bird such as *H. moquini*, and are therefore vulnerable locations for the species. In the case of birds undergoing migration or dispersal, roost sites also are important resting areas and tend to be in close proximity to sites where the birds refuel before continuing their journey. The use by other shorebird and seabird species of all but one of the oystercatcher roost sites indicates that these areas are especially significant.

Increasing holiday home development in the southwestern area of Western Cape Province, South Africa, could infringe on those areas used by oystercatchers and other shorebirds, and unmonitored or unregulated activities by the residents and their pets could disturb both roosting and foraging birds, and lead to trampling or predation of eggs and chicks. Disturbances to roosting and foraging birds by human development have been witnessed for this species (*pers. obs.*) and others (Burger 1991; Melvin *et al.* 1991; BirdLife International 2004a). Human disturbance can also compromise birds' survival by causing excess energy expenditure (Rehfisch *et al.* 1996, West *et al.* 2002, Rehfisch *et al.* 2003). Cumulative impacts of the escalating development in the southwestern area of Western Cape Province will include an increased human population and increased industrialization, likely accompanied by coastal roads and increased road traffic. Environmental impact assessments do not currently take these considerations into account (S. Ralston, Wildlife and Environmental Society of South Africa, *pers. comm.*).

The effects of the loss of an African Black Oystercatcher roost site were observed at Shell Bay, where a restaurant was constructed adjacent to the previous location of the roost. The roost has since scattered to the east and west of its original location; the maximum number of birds seen roosting has been reduced by approximately one-third relative to the numbers seen prior to the restaurant's construction (Oystercatcher Conservation Programme, unpublished data). Although it has not been possible to monitor mortality due to this alteration, it is possible that the birds' fitness may have been compromised due to reduced group vigilance against predators, including mammalian predators introduced as a result of human development (Chapter 1). The birds' resting and foraging time is also likely reduced due to displacement and flushing associated with increased human disturbance.

Mining can, at least temporarily, reduce the abundance of oystercatcher prey, thereby eliminating the area as foraging habitat. In Namibia and north-western South Africa, where mines are located and suitable foraging and roosting habitat is limited, it is especially important for areas used by the birds to be conserved (Barkai and Bergh 1992; Pallett 1995; Pulfrich *et al.* 2003 a,b,c; Chapter 4).

From the case of the African Black Oystercatcher, the following recommendations can be made to conserve roosting and associated foraging habitat along shorebird dispersal and migration routes:

In coastal development areas:

- Discourage ribbon development (i.e. development along an entire stretch of coastline) in favour of concentrated nodes (as per Department of Environmental Affairs and Tourism 2000) to ensure that undisturbed habitat remains for roosting, foraging and breeding shorebirds.

- Maintain undisturbed areas containing adequate habitat in order to allow birds to find sites that will allow them to avoid interactions with humans (Burger 1994, Rehfisch *et al.* 2003).
- Implement restrictions on pets and people around larger shorebird roosts.
- Improve signage and public education in shorebird roosting areas.

In mining zones:

- Do not allow coastal mining at sites used for roosting or foraging by shorebirds.
- Minimize coastal traffic associated with mining so as to reduce disturbance to roosting shorebirds.
- Install regular, independent environmental monitors at diamond mines.
- Educate mining staff regarding sensitive species and ecosystems, including shorebirds.

Future research may examine whether the locations, sizes and species composition of roosts change as development continues in southwestern South Africa. Although oystercatchers' mortality rate is too low to detect any effect due to disturbance, differences in fitness level may be extrapolated by examining whether there is a significant difference in the time immature birds at disturbed versus undisturbed sites along the dispersal route spend feeding, preening, resting, being alert and running or flying away.

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Chapter 4
Conservation Threats to African Black Oystercatcher (*Haematopus moquini*) Roosts on the South African and Namibian Atlantic Coasts

Abstract:
*Most African Black Oystercatcher (*Haematopus moquini*) roosts on the west coasts of South Africa and Namibia are not located in protected areas. Holiday home development in the Western Cape is a potential and observed threat to shorebird roosts, particularly as it has occurred without the completion of environmental impact assessments, and because further developments are occurring and planned without thorough consideration of their cumulative impacts. Habitat characteristics of locations at which developments are built or planned are often equivalent to the physical habitat characteristics that characterize most west coast oystercatcher roosts. Other threats include continued (illegal) use of off-road vehicles on beaches, coastal diamond mining and proposed oil and gas development. Diamond mining can, at least temporarily, reduce the abundance of oystercatcher prey in an area, thereby eliminating the area as foraging habitat. Recommendations are made regarding shorebird conservation along the west coasts of South Africa and Namibia. In particular, ribbon development on the coast should be discouraged to maintain undisturbed habitats, and coastal mining and mining-related activities should not be allowed in areas used by roosting or foraging shorebirds.*

Key words: *African Black Oystercatcher, development, diamond mining, habitat conservation, long-distance dispersal, off-road vehicles*

Introduction

This chapter discusses current threats to the conservation of ecosystems on the west coast of South Africa and Namibia, particularly as they apply to shorebirds such as the African Black Oystercatcher. To assess whether oystercatcher roost sites are in threatened areas, it presents the locations of roosts relative to protected areas and areas where human activities are taking place. Finally, it makes recommendations to minimize the effects of human activities on oystercatchers and other shorebirds on the west coast.

The African Black Oystercatcher (Haematopus moquini)

The African Black Oystercatcher is listed as *Near-threatened* on the IUCN Red List of threatened species (BirdLife International 2004b). Globally, the species is considered rare, with a world population of ca. 6700, 75% of which are in South Africa (Oystercatcher Conservation Programme unpublished data).

Resightings of individually-marked colour-banded birds have shown that juvenile or immature oystercatchers disperse once in their lifetimes, to a range of locations along the west coasts of South Africa, Namibia and southern Angola, and remain there for a few years before returning to their natal sites for the remainder of their lives. The same locations tend to be used year after year by different cohorts of birds (Hockey *et al.* 2003; Chapter 2). The sites between the birds' natal sites and the north-western extreme of their range may be used either as stopover sites or dispersal endpoints.

Like other oystercatcher species, the African Black Oystercatcher forms communal roosts at high tide when immature or during the non-breeding season (Hockey 1996). Roosts tend to be small, relative to those of other roosting bird species, and seasonally variable in size (Hockey 1985). Roost site fidelity is high. Roost sites on the west coasts of South Africa and Namibia are not selected randomly, but are chosen on the basis of various physical habitat characteristics (Chapter 3). In particular, roosts are located most often in wave-sheltered areas containing both rock and sand, and with a maximum angle of visibility greater than 180°. This being said, roost sites are located in a range of habitats, likely limited by the availability of ideal habitat, particularly at more northern latitudes. Maximum roost sizes are highest in sheltered areas close to river mouths. Oystercatchers forage at low tide at or near the same sites as their high-tide roosts. They also tend to roost in the same areas as other shorebird and seabird species, making these areas particularly important for conservation (Chapters 2 and 3). West coast roosting and foraging sites outside of the birds' main breeding range are particularly important for dispersing young oystercatchers, as they allow the birds to develop foraging skills without having to compete with more proficient adult oystercatchers (Cadman 1980, Goss-Custard and dit Durell 1987, Hulscher *et al.* 1996, Hockey *et al.* 1998, Leseberg 2001, Chapter 2).

Protected areas

Marine Protected Areas (MPAs) are evenly distributed around the South African coastline except in Northern Cape Province, which lacks adequate representation. MPAs in South Africa were largely established in an *ad hoc* fashion, and therefore do not necessarily adequately represent the ecosystems that should be prioritized for conservation (Hockey and Branch, 1997, Attwood *et al.* 2000). Namibia has one of the longest protected coastlines in the world, with approximately 1200 km of continuous coast southward from the Cunene River falling within national parks. There is a proposal to proclaim the Sperrgebiet area of Namibia, containing the diamond mining region, as a multi-use zoned National Park, which would result in partial protection of an additional 360 km of coast. Because of the high economic importance of the diamond mining industry, however, mining activities will continue there (Pallett 1995).

Potential conservation threats on the Atlantic coasts of South Africa and Namibia

Activities such as housing and other developments, as well as diamond mining, kelp harvesting and unregulated camping along the west coasts of South Africa and Namibia could potentially pose a threat to roosting shorebirds such as the African Black Oystercatcher. Another threat is the continued use of off-road vehicles (ORVs) on beaches, on which birds sometimes roost.

The west coast of the Western Cape Province of South Africa has been developing slowly every year, particularly in the area surrounding Saldanha Bay and on the Vredenburg Peninsula (see Figures 3.1, 4.1 and Supplement 3). Proposed developments include the construction of an off-loading bay and storage facility at Saldanha for oil imported from West Africa, a new oil pipeline from Saldanha to Cape Town and Mossel Bay (on the south coast), offshore oil and gas exploration, a waste dump, harbour development at Shell Bay and further coastal resort housing around and south of the Vredenberg peninsula (S. Ralston, Wildlife and Environmental Society of South Africa, *pers. comm.*; Figure 3.1). Although there is a severe housing shortage in South Africa for the more disadvantaged members of society (Bosman 2002), housing developments built and planned along the Western Cape coast are primarily holiday or resort communities.

Diamonds are one of South Africa's chief exports. Diamond mining takes place in the littoral and shallow sub-littoral coastal zones of northwestern South Africa, between the Olifants and Orange Rivers (Barkai and Bergh 1992). The coast of Namibia from Lüderitz to the South African border (see Figure 3.1) is also mined intensively, including both terrestrial and marine regions. Shallow-water diamond mining is carried out from shore as well as from nearshore vessels (Pallett 1995).

Kelp harvesting is a source of income in very impoverished areas. Several kelp harvesting concessions are held by individual operators covering 100 km of coastline or more, although the actual harvesting locations depend on where kelp washes up naturally (R. Anderson, Botany Department, University of Cape Town, *pers. comm.*). Kelp harvesting on the Namibian coast is increasing (Pallett 1995).

Unregulated informal camping takes place along the west coast north of the Olifants River, this disturbance being most intense in December and January (P. Kruger, DeBeers, *pers. comm.*). The South African government recently legislated a total ban on ORVs along its entire coastline (Department of Environmental Affairs and Tourism 2003, 2004), although enforcement is sporadic and inconsistent (*pers. obs.*).

Mussel aquaculture projects exist on the west coast of South Africa. It is possible that mussel or shellfish harvesting could increase (C. Attwood, *pers. comm.*).

Methods

Research was conducted on the west coasts of South Africa and Namibia in 2004 and 2005. Conservation issues were examined through literature reviews, personal observation and discussions with officials from DeBeers diamond mines, the West Coast National Park, Marine and Coastal Management (Department of Environmental Affairs and Tourism), the University of Cape Town, the Wildlife and Environment Society of South Africa and the Saldanha Municipality.

Results and Discussion

Oystercatchers and protected areas

There have been statistically significant increases in numbers of oystercatchers following protection measures, partially due to increased breeding success, but more likely due to increased settlement by pre-breeding birds in protected areas (D. Loewenthal, *pers. comm.*). Research conducted between 1991 and 2003 showed that breeding success changed based on the interactive effects of protection status (protected or unprotected) and presence or absence of the invasive mussel *Mytilus galloprovincialis*, which now represents a major food item for oystercatchers (Hockey 1996). In areas where *M. galloprovincialis* was present, breeding success was significantly higher in protected areas (0.93± 0.05 chicks fledged per pair per year) than unprotected areas (0.27 ± 0.05

chicks fledged per pair per year) (D. Loewenthal, A.S. Rao and P.A.R. Hockey, unpublished data).

On the southern African west coast, only roost sites at Kleineiland and those in northern Namibia currently fall within protected areas (Figure 3.1). Only the roost at Üilspëelduin will fall within a proposed marine extension to the Namaqualand National Park from the Groenrivier (30°50' S, 17°35' E) to the Spoegrivier (30°28' S, 17°22' E), pending negotiations with the diamond mining companies which currently own the adjacent coastal area (C. Attwood, *pers. comm.*). Roosts in southern Namibia will fall within the proposed Sperrgebiet National Park, although diamond mining would still be permitted there. Coastal protected area coverage is generally low in the Northern Cape (Figure 3.1), where many oystercatcher roost sites are located (Appendix 10).

Potential threats to conservation

Development: Developments now require the completion of Environmental Impact Assessments (EIAs), however certain developments under construction at the time of writing were approved prior to the enactment of EIA legislation and therefore did not undergo EIAs (J. Benjamin, Saldanha Municipality, *pers. comm.*). The current legal requirement (similar to other countries, including Canada) whereby developers themselves are required to commission the EIA represents a conflict of interest, as the consultants preparing the EIA statement report to the company whose primary interest is to push the development ahead. The EIA process requires public participation, however background documents are often in technical language and provided in locations that are inaccessible to the majority of affected people. Furthermore, developers also do not always build according to approved plans, and neither provincial nor municipal authorities have the capacity to conduct environmental monitoring of approved developments (J. Benjamin, Saldanha Municipality, *pers. comm.*; S. Ralston, Wildlife and Environmental Society of South Africa, *pers. comm.*).

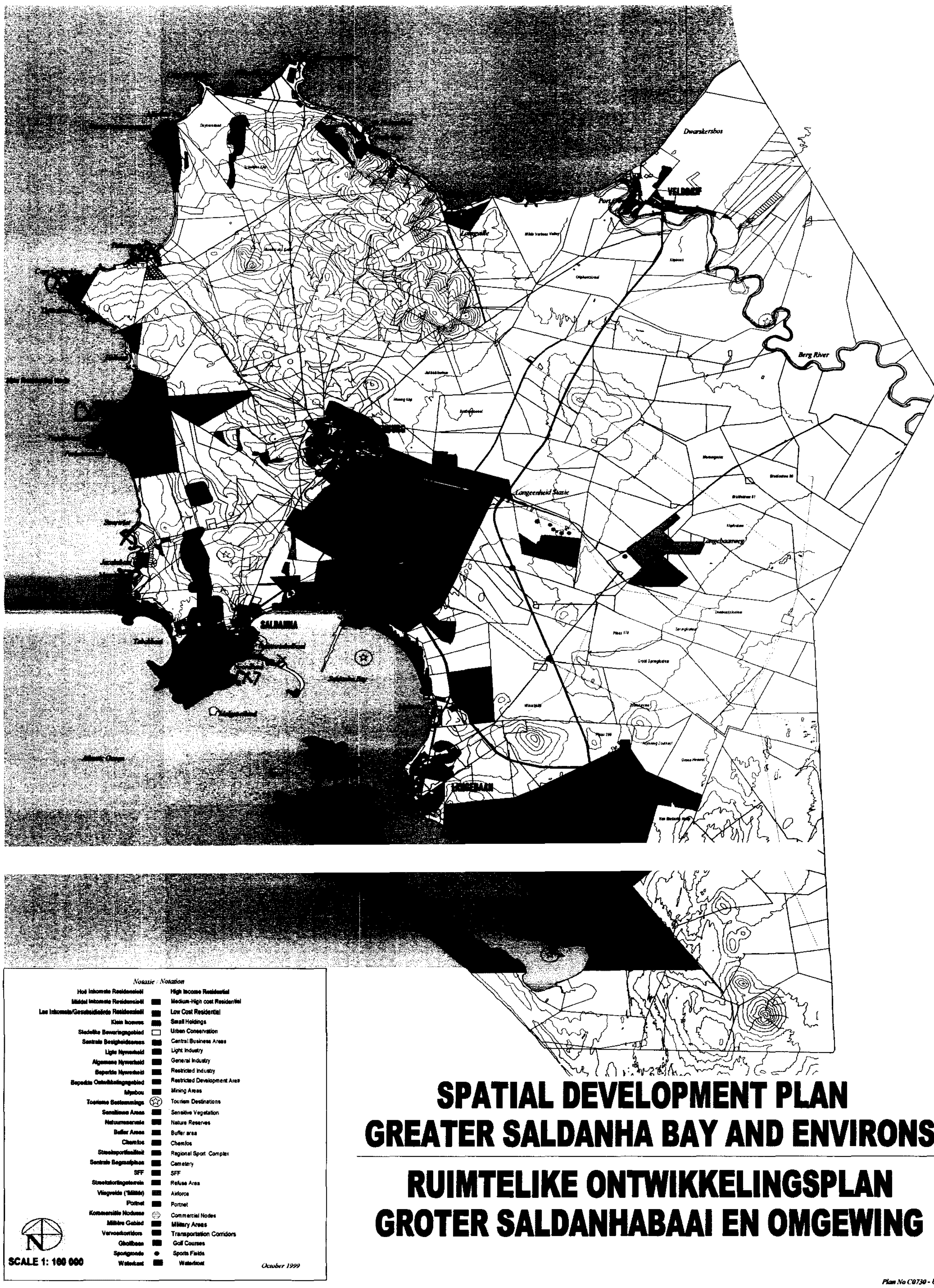
Oystercatchers forage around the whole Vredenburg peninsula in Western Cape Province and southward to Koeberg (Oystercatcher Conservation Programme unpublished data). Oystercatcher roosts exist on this peninsula at Mauritzbaai, Hospital Point, Shell Bay and Varkvlei, and seasonal roosts form in other locations such as Paternoster (Figures 3.1, 4.1). Seven of the nine areas scheduled for development on the peninsula, around several oystercatcher roosts, are zoned for high-income residential housing (Figure 4.1, Supplement 3). Furthermore, the physical attributes of areas scheduled for development are very similar to those at oystercatcher (and other coastal birds') roost sites. In particular, the majority of developments are scheduled for wave-sheltered areas with both sandy and rocky shores and a maximum angle of visibility greater than 180° (Table 3.4, Chapter 3). They are also located in areas relatively close to ephemeral or permanent river mouths, as are the larger oystercatcher roosts.

Although the impacts of each individual development must be considered, the cumulative impact of all current and planned developments is of prime concern. Cumulative impacts of the above developments will include an influx of people to the area; road development and traffic; increased presence of vehicles on the coast; and pollution, including oil spills. Specific effects on shorebirds will likely include increased access for domestic animals and other introduced predators, which can prey on adult birds, eggs and chicks; increased human disturbance through pedestrian traffic; and displacement or flushing of birds during foraging or roosting (Burger 1991; Melvin *et al.* 1991; Wildlife and Environmental Society of South Africa, *pers. comm.*; *pers. obs.*).

Negative effects of human development on shorebird habitats have been observed globally. For example, numbers of Whooping Cranes (*Grus americana*) decreased following human settlement (Allen 1952) and agricultural development in North America (Binkley and Miller 1988), and the species is now classified as *Endangered* (Government of Canada 2005). Also, as large areas of wetland in the coastal lowlands of southern Japan, southern China and northern Vietnam have been reclaimed for agriculture, aquaculture, industry, urbanization and port development, the extent and quality of wetland habitat have been reduced. In turn, wintering sites of shorebirds such as the Black-faced Spoonbill (*Platalea minor*) have been lost (BirdLife International 2004a).

Human disturbance itself constitutes habitat deterioration (Sutherland 1998). For example, within their overall potential habitat, Piping Plovers (*Charadrius melodus*) in New Jersey limit themselves to sites that contain the fewest people (Burger 1994). Human disturbance can also compromise birds' survival due to an increase in energy expenditure required to escape disturbance (Rehfisch *et al.* 1996, 2003). Increased development and human disturbance in Florida and New Jersey has led shorebirds to change their foraging patterns, in particular to reduce their foraging time and increase the amount of time spent flying, running or being alert in the presence of people (Burger 1994), and increase their nocturnal foraging time, with time per minute spent foraging increasing from 41.9 seconds during the day to 51.2 seconds at night (Burger and Gochfeld 1991). West *et al.* (2002) concluded that human disturbance to Eurasian Oystercatchers (*Haematopus ostralegus*) feeding in winter could be more damaging than permanent habitat loss, due to the loss of foraging time and hence energy following disturbance. In particular, their model suggested that many small disturbances would be more damaging than fewer, larger disturbances with respect to individual survivorship.

(On the following page:)
Figure 4.1. Planned developments on the Vredenburg peninsula, southwestern South Africa. X = oystercatcher roost location, (X) = former/seasonal oystercatcher roost location. (reprinted from Saldanha Bay Municipality 2000)



SPATIAL DEVELOPMENT PLAN
GREATER SALDANHA BAY AND ENVIRONS

RUIMTELIKE ONTWIKKELINGSPLAN
GROTER SALDANHABAAI EN OMGEWING

Plan No C0730 - U - P - 002 Revision A2 Date 03 04 2000

Diamond mining: Ten roosts are located in the Namibian diamond mining area, with two located in active mine sites (F. Olivier, NAMDEB, *pers. comm.*); eight additional roosts are in potential or active South African mining areas (Chapter 3, Figure 3.6).

Much of the Namibian coast is in pristine condition, but terrestrial and marine diamond mining has caused disturbance in several areas since the 1960s (Appendix 11). To facilitate access to underwater diamond deposits, supratidal and intertidal regions are often blasted or otherwise damaged. Dragging of hoses and machinery leads to trampling of biota and abrasion of the ocean floor. Boulders are also moved and piled by divers, dragged up the shore by tractors and chains, and overturned or broken to reach deeper deposits. Gravel around boulders is also removed. Rock removal destroys the biota in the area. After separation of diamond from gravel, fines (smaller particles) are sent as a slurry across the intertidal zone to the ocean, smothering the underlying biota (Pulfrich *et al.* 2003a).

Research conducted in Namibia from 1993 to 1999 identified reduced cover of filter feeders at mined sites in the first two years after marine mining ceased in an area. During this time, decreased grazer density following mining coincided with an increased density of foliose algae. Species richness decreased at mined sites. Recently mined areas contained diver-created rock-piles and boulder aggregations, which disturbed or buried benthic fauna on the rocks (Pulfrich *et al.* 2003a).

Fine sediments from terrestrial diamond mining are also pumped to the ocean, and overburden sand (see Figure 4.2) has been used to extend the beach by hundreds of metres. For example, fines sent to the ocean from Elizabeth Bay (Figure 3.1), the location of a relatively large oystercatcher roost, has expanded the beach outward by 200 m (Pallett 1995), as wave action is insufficient to disperse the quantity of sediment discharged (Pulfrich *et al.* 2003b). Sediment disposal on the rocky shores of Elizabeth

Bay smothers and dislodges limpets (Pallett 1995) and mine-affected sites have a lower density of patellid limpets in the intertidal zone (Pulfrich *et al.* 2003b).

Figure 4.2. Overburden dump and altered coastline in the diamond mining region of Namibia (photo D. Loewenthal)

The littoral and shallow sublittoral zones of the northwestern South African coast are also intensively mined for diamonds as described above and with similar physical impacts. Areas around South African mined sites contained lower intertidal species densities, including lower density of mussels *Mytilus galloprovincialis* and *Aulacomya ater*, which are prey items for African Black Oystercatchers. Nearby rocks were devoid of life. The impact on the intertidal zone of the equipment used in the pumping may be more significant than the pumping itself, and researchers have warned that damage can spread within the intertidal ecosystem, possibly to shorebirds if the area becomes less productive or frequently disturbed (Barkai and Bergh 1992).

Inadequate operational management of diamond mines, for example oil spills and waste dumping, may also harm wildlife and damage ecologically sensitive areas (Pulfrich *et al.* 2003c). Raising awareness of environmental issues among mine staff may be challenging in the case of companies such as Alexkor which outsource a large part of their work (Alexkor 2003; M. Louw, Alexkor, *pers. comm.*). Independent monitoring is also lacking in some circumstances. For example, Namaqualand Mines itself is responsible for reporting to the government regarding the quality of seawater used in its processes before it is pumped back to the ocean (P. Kruger, DeBeers, *pers. comm.*).

Because of the stringency of Namibian security procedures, little is known about the sensitive ecosystems in the Namibian diamond mining area. As a result, it is difficult to draw conclusions regarding any existing or potential effects that coastal mining has on oystercatchers or other shorebirds in southern Namibia, or to make recommendations to mitigate these impacts.

What can be said, however, is that specific effects on oystercatchers and other shorebirds could include the following, if diamond mining occurs in breeding, roosting and/or foraging areas:

- trampling of nests and chicks by people and vehicles on the coast;
- disturbance to the birds from human movement and activity on the coast;
- immediate reduction of food availability, including limpets and mussels, because of smothering by sediment discharge into the ocean;
- temporary or permanent displacement of birds due to disturbance or reduced food availability over a period of a few years.

<u>Tourism and recreation</u>: Coastal developments for tourism and recreation have irreversibly altered the South African coastline and increased human access to resources (Attwood *et al.* 2000). The coastal lowlands of the Western Cape have been subject to

resort and other development, as described above, which has resulted in habitat fragmentation (Heijnis *et al.* 1999). Further north, during December and January, 50-100 vehicles, largely 4x4 vehicles that could travel on the beaches, may be on the Northern Cape coast at any one time (despite the ban on ORV use on beaches). This activity is concentrated in the area from south of Mitchell's Bay (17°27'S, 30°30'E) to the border between Northern Cape and Western Cape Provinces (P. Kruger, DeBeers, *pers. comm.*). Tourism on the Northern Cape coast peaks during school holidays, at long weekends and in the September flower season. Tourist pressure along that coast is relatively low and is mostly concentrated around the Groenrivier area. There is no monitoring of camping or recreational activities along the west coast (P. Kruger, DeBeers, *pers. comm.*, C. Attwood, *pers. comm.*).

<u>Off-road vehicles:</u> Because the nests of mainland-breeding oystercatchers are unprotected scrapes on open beaches, any indiscriminate transportation over the beach poses a severe threat to their breeding success. Some roost sites also are located on beaches. Various sources surveyed in 2004 reported that there are fewer off-road vehicles on the coast since the ban on ORVs was implemented. At the same time, however, the implementation of the ban is the responsibility of whichever body controls the area of coastline in question, for example the federal government, the provincial government, the municipal government, or military or private landowners (C. Attwood, *pers. comm.*; P. Nel, West Coast National Park, *pers. comm.*). This will make the ban difficult to implement.

I observed vehicles travelling along the beaches at Elands Bay and the Olifants River mouth. In March 2005, four vehicles were observed driving on Elands Bay beach, across which the oystercatcher roost site is often scattered, in a 4-hour period, one of which drove directly in front of a police officer (Figure 4.3). I also observed tracks at

Hondeklipbaai (Figure 4.4). This suggests that the ban is being violated at some locations with impunity (Appendix 12).

Figure 4.3. Vehicle driving on Elands Bay beach (oystercatcher roost site) in front of police officer (photo A. Rao)

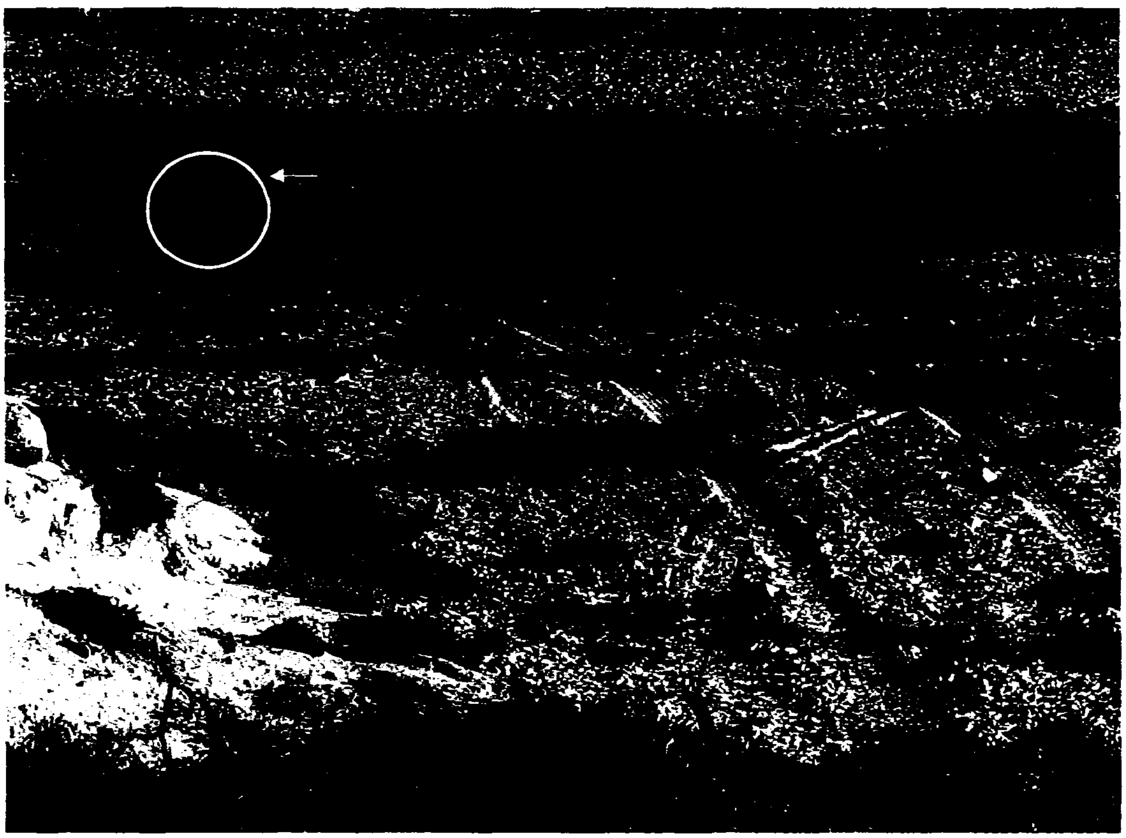


Figure 4.4. Vehicle tracks on beach adjacent to oystercatcher breeding location (photo M. Goren)

Kelp harvesting: The harvesting process involves a group of individuals who walk sections of the coast at low tide and carry washed-up kelp to locations above the high-water mark, where it is collected later by a tractor and trailer. Researchers estimate that the intensity and impact of kelp harvesting are low, given the infrequency and minimal nature of harvesting activities (R. Anderson, *pers. comm.*). The main risk of this activity to shorebirds is of the tractor crushing nests on beaches in breeding areas. Given the low intensity of the operation, however, this is likely not a serious concern for oystercatchers.

Shellfish harvesting and aquaculture: Intense shellfish harvesting was predicted to lead to local depressions of oystercatcher populations (Hockey 1996). In the case of aquaculture, sites in Ireland at which mussel longline aquaculture was practised showed higher bird species richness than control sites. Oystercatchers (*H. ostralegus*) and other species perched on mussel suspension buoys and fed on young mussels and epifauna attached to surface structures, as well as on the farmed mussels themselves. A potential negative impact was the relatively large number of gulls that were attracted to the structures, however their presence did not deter any other avian species (Roycroft *et al.* 2004).

Specific threats to roost sites

Below are listed roost sites that are potentially threatened by one or more activities:

Yzerfontein: This roost site is within the village of Yzerfontein. The birds at this roost were more habituated to humans than birds at roosts in less disturbed areas (*pers. obs.*). A new high-income housing development is proposed directly south of the roost, along a beach used by breeding birds, including oystercatchers. Predicted effects of this particular development on shorebirds include habitat loss, disturbance and mortality due to domestic animals (Withers 2005).

Mauritzbaai: Holiday homes were being built in 2004 directly adjacent to this roost. No environmental impact assessment of this housing development was conducted, as it had been planned prior to enactment of EIA regulations (Environmental Conservation Act no. 73, 1989) (J. Benjamin, Saldanha Municipality, *pers. comm.*). In 2004, construction was occurring within 50 m of the high water mark at some places. Construction vehicles were observed to have caused roosting birds to take flight. Mauritzbaai not only serves as a roost site for oystercatchers, but also for several other shorebird and seabird species, including Antarctic Terns (*Sterna vittata*) (Figure 3.6), a species whose numbers have decreased on the South African west coast in recent years (A.J. Tree, *pers. comm.*).

Hospital Point: This roost is sited close to holiday homes and in an area used for recreation.

Shell Bay: There is a very large and dense holiday-home development at Shell Bay, which was approved prior to the passing of the EIA regulations. A restaurant was constructed adjacent to the previous location of the roost. The roost has since changed locations and has scattered both to the east and west of the original location; the maximum number of birds seen roosting at Shell Bay has been reduced by approximately one-third relative to the numbers seen prior to the restaurant's construction (Oystercatcher Conservation Programme, unpublished data). Harbour development is also proposed in the area to which part of the roost has moved, which will result in increased human traffic and disturbance.

Elands Bay: More than 90 birds have been recorded roosting at one time at Elands Bay, however, the site is disturbed frequently as people drive, walk and take their dogs along the beach. The result is that the birds take flight easily and the roost often splits into several groups.

Brand se Baai: Diamond mining operations, both terrestrial and nearshore, began in 2004-2005 south of this roost. In 2005, large open pits and machinery were present close to the shoreline, but far enough south of the roost location so as not to cause disturbances.

Malkopbaai, Island Point and Üilspëelduin: In 2004, DeBeers was pumping the nearshore area (prospecting for diamonds) around Groenrivier prior to relinquishing their mineral rights to the proposed Namaqualand National Park; they had not recovered any diamonds as of June 2004. They have since moved their prospecting operations away from the Groenrivier area. There is currently no mining planned for Island Point (P. Kruger, DeBeers, *pers. comm.*), but the area where tourism is concentrated, i.e. the Groenrivier area, is close to the roosts at both Island Point and Üilspëelduin. The latter roost, however, was inaccessible in May 2004 even with a 4x4 vehicle. The roost sites at Malkopbaai and Island Point are adjacent to designated campsites, to which people are requested to confine themselves. Camping at the designated campsite at Island Point during a field trip in February 2005 did not cause any obvious disturbance to oystercatchers, which roosted and foraged on a large offshore rock. The Malkopbaai roost is more accessible to humans, and the campsite is closer to the roost location, making disturbance more likely.

During school holidays, long weekends and the September flower season, between 4 and 20 individual 4x4 cars and convoys of up to 40 4x4 vehicles at a time may drive the road between the Spoeg and Groen Rivers, which includes passing the roost at Üilspëelduin. Several side roads off of this road lead directly to the coast. This coastal area between the two rivers is being proposed as a national marine protected area; however, there is limited monitoring of activities in this area at the present time (E. Hough, Die Honnehok guest house, *pers. comm.*).

Hondeklipbaai: The roost is located near a small town, and boat-based diamond dredging activities take place a few hundred metres offshore (see Figure 4.5), but no dredging or other mechanical disturbance was observed in the intertidal zone. Tourism in Hondeklipbaai peaks during December and during Easter holidays. Tourist activities include diving for crayfish (rock lobster), collection of mussels, periwinkles and limpets, and recreational activities at the beach near the southern shipwreck (where two pairs of oystercatchers breed). Some off-road vehicles are driven on beaches and dunes, and local people have identified this as a "major problem" with respect to impacts on wildlife. The local police have recently been making greater attempts to enforce the ORV ban. Environmental education for tourists in the area is primarily provided by a local guest house; however, they still experience problems with individuals from nearby towns who are accustomed to previous lack of enforcement and do not comply with modern regulations (E. Hough, *pers. comm.*).

Figure 4.5. Diamond boats anchored in Hondeklipbaai (photo A. Rao)

Kleinsee: This roost is located on a recreational beach within a mining community. The roost can be located in various places along the beach (P. Kruger, DeBeers, *pers. comm.*). In close proximity to the beach are a series of braai (barbeque) pits. Newsletters and information regarding oystercatchers and their movements have been provided to the community.

McDougall's Bay: Two roosts were located at McDougall's Bay, one adjacent to a housing development and another south of a crayfish processing factory. The roost near the housing development extended quite far onto offshore rocks, and birds were therefore protected to some extent from disturbance from human traffic. These roosts are also unique in that the birds forage in the vicinity at both low tide (on rocks) and high tide (on wash-up and exposed rocks). The nearshore area adjacent to the birds' foraging area is a mining zone, although mining is not currently taking place due to its proximity to houses (P. Setzer, Alexkor, *pers. comm.*)

Namibia: Ten roosts were located by aerial survey in the diamond mining region south of Lüderitz (Figure 3.1). The impact of mining activities on those roost sites could not be assessed in more detail, however, due to the area's inaccessibility.

Thus, potential threats to oystercatchers and the other shorebirds that use the areas in which they roost can be summarized as follows:

- Increasing holiday home development in the southwestern area of the Western Cape Province could infringe on those areas used by oystercatchers and other shorebirds, and unmonitored or unregulated activities by the residents and their pets could disturb both roosting and foraging birds, as well as lead to trampling or predation of eggs and chicks.
- Cumulative impacts of the escalating development in the southwestern area of the Western Cape Province will include an increased human population and increased industrialization, likely accompanied by coastal roads and increased road traffic. Environmental impact assessments do not currently take these considerations into account.
- Mining can, at least temporarily, reduce the abundance of oystercatcher prey, thereby eliminating the area as foraging habitat. In Namibia and north-western South Africa, where suitable foraging and roosting habitat is limited, it is especially important for areas used by the birds to be conserved.
- Tourism in the Northern Cape is at very low intensity relative to other areas of South Africa's coast; the coast is rarely visited, and the resident population density is also low, with most of the area taken up by mine-owned property or large ranches with relatively

few livestock. That being said, there is currently no monitoring of this area to ensure environmental responsibility.

Recommendations

To municipalities (e.g. Saldanha Municipality):

- Discourage ribbon development (i.e. development along an entire stretch of coastline) in favour of concentrated nodes (as per Department of Environmental Affairs and Tourism 2000) to ensure that undisturbed habitat remains for roosting, foraging and breeding shorebirds.
- Use information from this document regarding the location of oystercatcher (and other coastal bird) roosts prior to planning or installing further developments along the coast.
- Maintain undisturbed areas containing adequate habitat to allow birds to find sites that will allow them to avoid interactions with humans (Burger 1994, Rehfisch *et al.* 2003).
- Provide training to town planners in environmental management and environmental impact assessment or have at least one environmental officer for each municipality, with a mandate that includes regular inspections for prevention of environmental mismanagement, and follow-up action in the event of conservation violations.

To national and provincial governments (Marine and Coastal Management):

- Implement restrictions on pets and people around larger shorebird roosts.
- Improve signage and public education in shorebird roosting areas.
- Ensure that environmental impact assessments of proposed developments consider the cumulative impacts of all proposed developments and are carried out by independent consultants reporting to the public at large and not to the developers.
- Install regular, independent environmental monitors at diamond mines.

- Make regular monitoring and enforcement of the ban on off-road vehicles a centralized responsibility.
- Provide information on roost site locations and how not to disturb roosting birds to people camping along the west coast at any physical locations or websites that individuals would consult when obtaining information to plan their trip.

To diamond mining companies:

- Do not allow coastal mining in areas important for roosting or foraging by shorebirds such as oystercatchers; as a start, avoid the roost site locations presented in this thesis.
- Confine landscape alterations such that they do not impinge on areas used by roosting and foraging birds.
- Minimize coastal traffic associated with mining so as to reduce disturbance to roosting shorebirds.
- Educate mining staff regarding sensitive species and ecosystems, including shorebirds.
- Allow the installation of regular, independent environmental monitors at diamond mines.
- Ease restrictions in the diamond mining areas in Namibia so as to allow access to conservation researchers

To kelp harvesting authorities (Marine and Coastal Management; Fishing and Mariculture Development Association):

- Make kelp harvesters aware of the possibility of nesting and roosting birds, and ask them to use caution when using tractors on beaches, ensure that their proposed route does not contain nests and ensure that their activities will not result in prolonged or sustained disturbance during a 4-hour period around high tide at roost sites.

To researchers:

- Monitor Mauritzbaai to determine the impacts of construction and housing developments on diversity and numbers of birds foraging and roosting at the site.
- As development continues on the Vredenburg peninsula, do the locations, sizes and composition of roosts change?
- Determine whether disturbance at roost sites affects the birds' fitness level by examining whether there is a significant difference in the time immature oystercatchers at disturbed versus undisturbed sites along the dispersal route spend feeding, resting, being alert and running or flying away.

In conclusion, the importance of west coast roosting and foraging areas both to resident African Black Oystercatchers and to young dispersing oystercatchers developing their feeding skills emphasize the need for their conservation. Although the population density on the west coasts of South Africa and Namibia is low, development in the south-west and mining in the north-west can pose threats to roosting and foraging oystercatchers. Few oystercatcher roosts are located in protected areas, meaning that measures should be taken by west coast land users to mitigate or minimize their potential impact on the birds.

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Chapter 5
Summary

Traditional, multi-purpose (stopover and endpoint) sites used by juvenile and immature African Black Oystercatchers (*Haematopus moquini*) during dispersal were identified along the Atlantic coasts of South Africa and Namibia. The species' dispersal pattern is not dichotomous as was previously hypothesized, but continuous. The sites that fall outside of the birds' breeding range are of particular importance as they allow immature birds to develop foraging skills in the absence of adult competitors. Of those birds whose movement endpoints were confirmed, 65% dispersed to Namibia (north of Lüderitz), 11% dispersed to north-western South Africa, 19% dispersed within south-western South Africa, and 5% dispersed along the south coast of South Africa (Chapter 2). Other shorebird or seabird species were present at all but one roost checked, indicating that the sites are important from a multi-species perspective (Chapter 3). The birds do not only begin long-distance dispersal as juveniles, as was previously hypothesized, but may begin travel at various ages while immature, and return to the vicinity of their natal sites between their second and fifth years, prior to breeding for the first time. The traditional nature of these sites and the roles they play in the development of a subset of young oystercatchers emphasize their conservation importance (Chapter 2).

These findings highlight the importance of tracking bird dispersal routes in order to improve understanding of a species' population ecology and life history and to identify sites of conservation importance, to be presented to the conservation community as well as developers.

There are no significant differences in body condition, relative hatch date or sex between oystercatchers dispersing to different distances. Birds of different origins and ages often mix along the dispersal route.

Increased mussel (*Mytilus galloprovincialis*) abundance and decreases in human disturbance of breeding areas following protection measures independently and jointly result in increased breeding success. This in turn leads to increases in local population numbers, followed by density-dependence forcing increasing numbers of young birds to disperse to more distant sites to avoid competition with adults. Thus, although the mussel invasion is altering the indigenous make-up of the intertidal zone, its effects are beneficial to a Red-Listed species (Chapter 2).

It may be concluded that ideal oystercatcher roost locations on the Atlantic coast of southern Africa are characterized by shelter, wide visibility angles and the presence of other avian species, all of which allow for predator avoidance. They may also be in close proximity to food such as limpets. All this being said, roost sites are located in a range of habitats, their location likely limited by the availability of ideal habitat, particularly at more northern latitudes (Chapter 3). The variety of habitat types that I have shown to be important to oystercatchers and other shorebird and seabird species forces us to question our assumptions regarding 'ideal habitat'.

Development is occurring in the southern part of the birds' dispersal route, particularly on the Vredenburg Peninsula, Western Cape Province, South Africa. The physical habitat characteristics of areas zoned for human development on this peninsula are similar to the characteristics of most oystercatcher roosts. Several roosting and foraging sites in Northern Cape Province and Namibia are located in diamond mining concessions. Mining can, at least temporarily, reduce the abundance of oystercatcher prey, thereby eliminating the area as foraging habitat. In Namibia and north-western

South Africa, where suitable foraging and roosting habitat is limited, it is especially important that areas used by the birds be conserved (Chapters 3 and 4).

The conservation importance of the sites identified in Chapter 2 is clear, both for the African Black Oystercatcher and other shorebird and seabird species in southern Africa. Few of these sites fall within protected areas, however, meaning that land users should participate in conservation activities. In particular, diamond mining companies, the South African and Namibian national and provincial governments, municipalities, developers and kelp harvesters should take several steps to minimize the impact of their activities on roosting and foraging shorebirds, in particular African Black Oystercatchers, on the west coast of southern Africa. Most of these steps involve increasing resource users' awareness of key habitats used by roosting, foraging and breeding shorebirds and ensuring the preservation of an adequate amount of undisturbed habitat (Chapter 4).

Threats faced by the African Black Oystercatcher are similar to those faced by shorebirds in other locations, including North America. Presentation and discussion of these similarities adds to the global voice for the regulation of potentially destructive or disturbing activities. This study shows that it is important to identify developers and resource users who operate in sensitive areas, and inform them about sites of conservation importance. Direct contact with such parties during the course of this research has proven to be helpful; in some cases they are interested in mitigating the environmental impact of their activities, however, they require appropriate information.

Several studies may serve as follow-ups to this project in the fields of oystercatcher dispersal ecology and shorebird conservation. Researchers may examine whether the proportion of oystercatchers that travel longer distances increases as the population size increases. With regard to characteristics that differentiate individual birds dispersing different distances, researchers may follow future generations to determine whether the offspring of banded birds follow the same dispersal pattern as their parents.

The impact of coastal developments on shorebirds may be assessed in more detail by examining whether the locations, sizes and species composition of roosts change as development continues on the Vredenburg Peninsula. Particular attention should be given to the roost site at Mauritzbaai, where development is currently taking place. Although oystercatchers' mortality rate is too low to detect any effect due to disturbance, differences in fitness level may be extrapolated by examining whether there is a significant difference in the time immature birds at disturbed versus undisturbed sites along the dispersal route spend feeding, preening, resting, being alert and running or flying away.

This study of the dispersal of young African Black Oystercatchers contributes to our overall understanding of the population ecology of the species and raises many questions about the impact of human influences on the coastal zone.

Appendices

Appendix 1. Planning process for the aerial surveys

Prior to doing the surveys, relevant officials at the various mining companies owning the coastal areas were contacted to inform them of the dates and details of the survey, ask for their acknowledgement that the survey would take place, and ask about restricted flying space and blasting times. The companies in question were TransHex, DeBeers, Namakwa Sands, Alexkor, and Namdeb. Relevant officials included persons responsible for access control, as well as environmental officers.

Logistics were closely coordinated with the pilot. The pilot's preflight planning checklist was as follows:

Before flight:

- book airplane
- check number of hours remaining before maintenance inspection and compare with number of hours required for flight
- check availability of landing strips and services offered, e.g. fuel, customs
- copy information of strips intended for use from Aeronautical Information Publication: runway length, elevation etc.
- do flight and fuel planning
- consider time of flight, airspaces restrictions, alternate landing fields
- pack kit to secure aeroplane at away field: oil, spark plugs etc.
- phone airfields for hours of fuel upliftment and contact numbers of refuelers
- check weather
- organise transport to and from airfields

On the flight

- contact meteorologist for update
- file flight plans and search and rescue, especially when flying over uninhabited terrain
- check fuel planning
- check that fuel used equals fuel use estimates

Due to the fixed window during which the survey could be conducted and limits on the availability of landing strips with fuel, the coast was divided into sections for the survey:

Survey 1, May 4-7, 2004, Elands Bay to Lüderitz:

Day 1: Elands Bay to Koiingnaas

Day 2: Alexander Bay/Orange River mouth to Lüderitz and back (completed as a flyover, as we could not get permission to land in Namibia)

Day 3: grounded due to high winds

Day 4: Alexander Bay to Koiingnaas (only portions of this were done due to fog)

Survey 2, August 28-30, 2004, Lüderitz to the Kunene River:

The areas of Walvis Bay and Swakopmund themselves were not surveyed, as the presence and sizes of roosts there were already known. Again, the coast was divided into sections surveyed over three days:

Day 1: Swakopmund to Lüderitz and return (southbound before and at the beginning of the high tide window; the section was then repeated northbound over the high tide window)

Day 2: Swakopmund to Möwe Bay

Day 3: Möwe Bay to the Kunene River and return.

Appendix 2. Roost site locations, tabular format

Table A1 summarizes the locations of roost sites seen during the May 2004 aerial survey from Elands Bay, South Africa to Lüderitz, southern Namibia, numbers of birds counted at each site, the accessibility of each site and the priority each South African site was ranked for ground-truthing. Because of limited time and resources, and the long driving distances between sites, those areas that were most accessible and contained at least 10 birds were ground-truthed. The latter criterion was developed because roosts (or aggregations seen from the air) of a smaller size could likely be convergences of breeding pairs rather than an established roost that may contain juveniles or other immature birds. Southern Namibian sites could not be ground-truthed due to the extemely complicated security process imposed by the diamond mining company, Namdeb. This process could not have been completed during the duration of this research project. The Namibian sites were thus considered, for all intensive purposes, inaccessible. Although the Lüderitz area is a public zone and roosts were observed there from the air, it contains several resident oystercatchers which would likely account for the majority of birds at roosts in the area. Thus, given the likely lack of banded birds and the expense of travel from Cape Town to Lüderitz, it was decided to not ground-truth the Lüderitz sites.

Table A2 summarizes the locations of roost sites seen during the August 2004 aerial survey from Lüderitz to the Cunene River, and the number of birds counted at each site. Again, those sites with at least 10 birds can be more confidently considered to be roosts.

Table A1. Roost sites located during May 2004 aerial survey (Elands to Lüderitz)

Roost Location (south to north)	No. seen	Accessibility	Priority
South Africa			
Brand se Baai/Blinkwaterbaai 31°17-18' + Stompeneus? 31°22'	group 2		mid low

Roost Location (south to north)	# seen	Accessibility	Priority
Titiesbaai/Grysduin/Malkopbaai/ Soutrivier 31°13'	30		high
Island Point 30°55'	20 + 2		high
Uilspieëlduin 30°40-41'	10 + 2		high
Strandfontein 30°33-34'	3		low
Hondeklipbaai 30°19 + Grysduin? 30°22.23' + 30°14.38' ?	15-20 + 5	open access	high
Voëlklip/Bamboesbaai/Noepbaai? 30°06.67'	?	De Beers "easy" access	mid
north of Witstrandjie 29°45.87'	5-10	"	mid
Kleinsee? 29°41.47'	?	"	
29°26.37'?	?	De Beers "difficult" access	low?
Port Nolloth (McDougall's Bay)	not seen	open access	high
29°07.42'?	?	Alexkor	low
south of oyster farms 28°50.05'	5	Alexkor	low
Namibia			
28°30-31'	10	Namdeb	
28°08'	10-20	Namdeb	
28°03.20' (part of other roost?)	7	Namdeb	
Panther Head/Chameisbucht/ Roastbeef Island	7	Namdeb	
south of Bakers Bay 27°43-44' 27°45'	2-8 + 1	Namdeb; no evidence of human activity in area	
Driemasterbaai 27°32-33' 27°31.50' 27°30-31'	16-20 among all sites - were north sites from Bogenfels roost?	Namdeb	
Bogenfels Arch 27°27-28'	5-18	Namdeb; tourism access?	
Van Reenenbaai/Black Knoll + 27°22.40'-23.00'	4-6	Namdeb; no evidence of human activity in area	
Pomona Island & vicinity + Second Rock vicinity + 27°15.00'-16.80'	90+ + 2-4 + 7-15	Namdeb; mine camp nearby	
Prinzen Bucht/Albatross Rocks + south of Possession Island 27°02.20-68'	2-6 20+ part of EBay?	Namdeb	
Elizabeth Bay area: 26°58.75' 26°56.80' 26°56.00' Elizabeth point east Elizabeth point west 26°54-55' 26°33.18-39'	58-85+ total: 8-15 ? 15-20 2 30+ 1-6 2	Namdeb	
Lüderitz area: Halifax Island Guano/Shearwater Bay across from Penguin Island Agate Beach west of Flamingo Island	147+ 50+ 10+ 2 15 70+	open access	low (likely resident populations)

Table A2. Roost sites located during August 2004 aerial survey (Lüderitz to Cunene River)

(2004 survey data from P.A.R. Hockey, unpublished data; historical data from Berry and Berry 1975; Leseberg 2001; M. Boorman and S. Dantu, unpublished data; R.E. Simmons and J.P. Roux, unpublished data)

Locality	Latitude (degrees, minutes, decimals)	Estimated number seen
Douglas Point to Ichaboe Island	26° 18.86	36-62 during survey; 104 in November 2000
Witklip to Hottentot's Point	26° 08.75	9-19 during survey; 111 in November 2000
Black Rock	26° 05.10	9
Gibraltar	26° 00.70	13
Opp. Saddle Hill Camp	25° 56.70	1
Saddle Hill South	25° 55.60	1
No name	25° 52.30	14
N of Clara Hill	25° 46.50	11-20
North Point	25° 41.31	1; 10 immature seen at Spencer Bay in Nov. 2000
North Head	25° 39.54	4
vicinity of	25° 33.30	9-19
Knoll Point	25° 27.03	2
No name	25° 22.97	1
No name	25° 21.95	2
Oyster Cliffs	25° 20.48	1
Easter Point	25° 17.20	16
Sandwich Harbour	23° 22.32	38; up to 130 seen in 1970s; <10-35 in 1990s; 10-20 in 1999-2001
Walvis Bay	22° 58	Not surveyed; avg 38 in 1980s, avg 125 in 1990s; 100-160 from 1999-2001
Pelican Point	22° 52.70	5 (part of Walvis Bay?)
Swakopmund	22° 35-36	Not surveyed; avg 11, but up to 60 in past; numbers fluctuate seasonally, peaking in May-June; 5-40 seen 1998-2000
Cape Cross Bay	21° 45.0	None during survey; up to 12 seen before
Ugab Salt Works	21° 23.0	None during survey; seen before
Ogden rocks	21° 08.0	None during survey; seen before
Toscanini	20° 50.0	None during survey; seen before
N of Toscanini	20° 47.35	2
Rotsagtig	19° 30.155	6
Hoanibmond	19° 28.5	None during survey; 35 present during previous surveys
No name	19° 7.39	1

Appendix 3. Roost site data collection form

Roost Number and Location:__________________ **Date & Time Checked:** ________________
Observer: __________ **Weather:** ___________ **High tide height/time:** __________________
Latitude x Longitude: _____________ **GPS reading:** ______________ **Marked on Map:** ☐

FD = from distance; FC = from close; A = anytime at roost site; P = post-observation; O = opportunistically; CM = continual monitoring

Roost Size / Members:

FD	Total # of individuals				total: 1st-year: non 1st-year: moult:	
FD/FC	Total # of confirmed ringed individuals				total: 1st year: obvious male: obvious female:	
FD/FC	Total number confirmed unringed individuals				total: 1st year: obvious male: obvious female:	
P	Roost catchment area (km on either side)					
FD/FC	Other bird species present					
FC	Rings: right leg:	left leg:	bird origin:	bird age:	destination: nursery/natal site; specify	comments:
					(determined after checking records)	

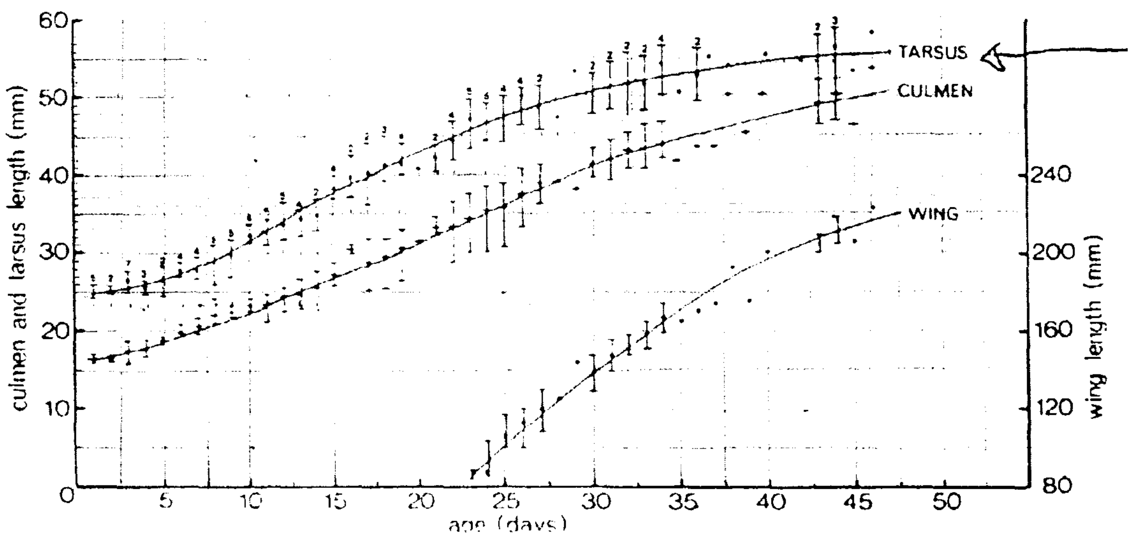
Behaviour, Disturbance:

FD	Density of individuals (crowded, semi-crowded, sparse)	
FD	Vocal? (yes/no)	
FD/FC	Activity	
O	# and nature of disturbances	
O	Birds' response to disturbances	
O	Mortality?	
P	Human population density in area	
P	Roost site located in protected area? (yes/no; if yes, specify)	yes (specify:) no
P	Located in mining or other human use zone?	yes (specify:) no
P	Other comments	

Physical Characteristics of Roost Site at High Tide:

A	Exposure to wave action relative to adjacent coast	less equal greater
A	Substrate (sandy, shell-covered, rocky shore, wave-cut platform, boulder beach)	
A	Slope - scale of 0 to 3 (0 = flat, 3 = steep)	
A	Distance from high water mark	
A	Offshore rocks present nearby?	yes no
A	Proximity of roost site to nearby offshore rocks	(estimate)
A	Promontory present?	yes no
A	Roost sited on promontory?	yes no
A/P	Proximity of river mouth	
A	Angle of roost: 0° 45° 90° 180° 360°=offshore rock	
P	Other comments	

Appendix 4. Figure from Hockey (1984) showing relationship between mass in grams and tarsal length in millimetres for African Black Oystercatcher chicks



Appendix 5. Characteristics of individually resighted birds, and distances traveled

Bird Band Number	Confirmed max. shoreline location	Confirmed maximum distance travelled (km)	Mass	Tarsus	Mass/ tarsus	Relative hatch date	Sex 1=male, 2=female
AA4 m	7307	1442	495	54.4	9.099	74	1
AA5	7370	1519	387	51.1	7.573	83	
A10	7370	1519	414	51.9	7.977	82	
A26	7307	1456	480	57	8.421	68	
A27	7370	1533	385	54	7.130	79	
A33	6875	1024	340	46.4	7.328	92	
A36 m	7307	1456	502	58	8.655	69	
A45	7307	1456	470	52.5	8.952	82	
A47 f	7307	1451	530	57.2	9.266	70	
A50	7307	1451	495	55.7	8.887	71	
A51	7370	1528	335	49.5	6.768	89	
A68	5881	23	140	39.3	3.562	75	
A80	7241	1390	500	53.9	9.276	99	
A88	5812	53	260	44.8	5.804	117	
101	5881	25	260	43.8	5.936	51	
107	6164	304	275	46.4	5.927	50	
115	7307	1472	275	47	5.851	51	
117	5913	61	340	50.3	6.759	45	
135	7307	1456	380	51.8	7.336	69	
152	7370	1533	315	52.2	6.034	104	
179	7307	1456	374	55.7	6.714	61	
184	5812	49	341	51.2	6.660	108	
191	6016	155	426	53.4	7.978	102	
192	7307	1456	461	57.7	7.990	92	
205	7307	1442	288	47.5	6.063	160	2
209	7307	1442	447	55.4	8.069	144	1
258	6211	351	445	54	8.241	78	
300	6211	351	323	52.6	6.141	96	
XX5	7307	1499	410	53.6	7.649	40	
X12	7307	1499	480	56	8.571	33	
X17	5956	148	535	60.3	8.872	35	
X19	7307	1499	575	58.6	9.812	36	
X20	7307	1499	565	56.6	9.982	36	
X21	5881	75	510	58	8.793	38	
X28	7370	1576					
X32	7241	1499	300	46.8	6.410	73	
X37	5812	4	535	59.5	8.992	51	
X40	7370	1576	495	60.8	8.141	51	
X51	7307	1499		52.8		129	
X59	6211	403	236	42.8	5.514	18	
X64	7241	1433	490	54.9	8.925	10	
X68	7307	1499	230	42.4	5.424	39	
X70	7307	1499	310	48.1	6.445	33	

X73	7307	1499	215	42.8	5.023	39	
X76	7307	1499	460	55.3	8.318	17	
X77	7370	1576	426	51	8.353	30	
X85	5812	4	410	51.6	7.946	76	
X86	7370	1576	280	46.5	6.022	104	
X89	5812	4	560	58.9	9.508	61	
X91	7307	1499	505	57	8.860	88	
X92	5684	125	440	51	8.627	142	
X98	6016	208	229	46.4	4.935	55	
103	7307	1499	244	45.7	5.339	67	
104	6094	296	289	50.6	5.711	60	
108	7241	1433	419	57.5	7.287	44	
110	7370	1576	319	49.2	6.484	64	
111	7370	1576	369	50.5	7.307	61	
112	5840	286	449	55.9	8.032	50	
114	6016	208	549	60.3	9.104	51	
116	7370	1576	454	57.4	7.909	51	
118	7307	1499	199	45.1	4.412	78	
120	6016	208	274	47.1	5.817	76	
121	7307	1499	286	48.9	5.849	75	
123	6016	208	304	51.1	5.949	78	
124	6094	286	399	56.2	7.100	62	
131	7241	1433	480	55.8	8.602	96	
133	7307	1499	525	58.3	9.005	97	
148	7307	1499	407	58	7.017	22	
178	7307	1499	442	56.9	7.768	48	
183	6094	208	187	42.4	4.410	51	
193	6164	356					
194	6149	341					
EE1	6016	46	470	55	8.545	80	
EE7	7370	1557	132	35.5	3.718	79	
E15	6016	348	410	59.3	6.914	38	
E27	7370	1629	515	63.3	8.136	66	
E37	7307	1625	446	53.1	8.399	73	
E39	6016	473	338	48.4	6.983	107	
E42	7241	1559	326	51.1	6.380	133	1
E71	7307	1566	335	53	6.321	86	
E79	7370	1629	500	60.6	8.251	79	
111	7241	1500	315	48.4	6.508	9	
HH2	7370	1848	335	46.9	7.143	103	
HH3	7307	1869	300	48.3	6.211	109	2
HH9	7307	2001	190	41.3	4.600	70	
H13	7307	1954	310	55.4	5.596	34	
H25	6094	510	370.5	61.1	6.064	60	
H27	7307	1723	372.5	55.8	6.676	127	
H31	6843	1232	401	51.1	7.847	66	
H33	7307	1723	365	50.5	7.228	97	
H34	7307	1723	485	54.7	8.866	117	
H59	7307	1869	426	53.3	7.992	101	

H61	7307	2001	212	46.5	4.559	54	
M19	7307	2297	350	49.3	7.099	61	
M32	5101	92	305	51.5	5.922	19	
M35	4796	245	255	45.2	5.642	30	
M45	7307	2328	345	50.8	6.791	51	
M53	7370	2396	125	36	3.472	58	
M56	7370	2329					
M72	7307	2298	330	51.4	6.420	29	
M84	6094	1053	305	52	5.865	24	
M86	6282	1241	359	53.5	6.710	46	
M94	7307	2285	310	51.7	5.996	63	
TT6	5101	338	385	53.4	7.210	118	
T14	5103	324					
X10	4723	274	504	57.8	8.720	49	

Appendix 6. Detailed table showing natal origins of oystercatchers seen at ground-truthed roosts

	Roost																
Region of natal origin (northwest to southeast)	**Koe-berg**	**Yzer-fontein**	**Klein-eiland**	**Mauritzbaai/ Hospital Point**	**Shell Bay**	**Varkvlei**	**Elands Bay**	**Olifants River**	**Brand se Baai**	**Malkop-baai**	**Island Point**	**Honde-klipbaai**	**McDougall's Bay**	**Douglas Point**	**Hotten-tots Bay**	**Sandwich Harbour**	**Walvis/ Swakop**
Saldanha Bay islands all		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Jutten Island		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓
Malgas Island		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓				✓
Marcus Island		✓		✓	✓	✓	✓										✓
Schaapen Island				✓													
unknown						✓	✓	✓					✓				
Dassen Island all		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Lambert's Bay to Cape Point all		✓		✓	✓	✓	✓	✓				✓	✓			✓	✓
Robben Island		✓			✓		✓	✓					✓			✓	✓
Kommetjie/Soetwater							✓						✓			✓	✓
Noordhoek								✓								✓	
Holbaai-Melkbos							✓										
Dwarskersbos					✓	✓	✓										
Yzerfontein					✓		✓										
16-Mile Beach		✓															✓
unknown				✓	✓	✓	✓	✓				✓	✓				
Cape Point to Breede River all								✓					✓		✓		✓
AECI Strand																	✓
Betty's Bay																	✓
Dyer Island																	✓
De Hoop																	✓
De Mond																	✓
Strandfontein															✓		
unknown								✓					✓				
Breede River to Cape St. Francis all		✓					✓	✓			✓	✓	✓				✓
Gericke's Point								✓				✓					✓
Goukamma Nature Reserve		✓															
Knysna							✓						✓				✓

Region of natal origin (northwest to southeast)	**Koe-berg**	**Yzer-fontein**	**Klein-eiland**	**Mauritzbaai/ Hospital Point**	**Shell Bay**	**Varkvlei**	**Elands Bay**	**Olifants River**	**Brand se Baai**	**Malkop-baai**	**Island Point**	**Honde-klipbaai**	**McDougall's Bay**	**Douglas Point**	**Hotten-tots Bay**	**Sandwich Harbour**	**Walvis/ Swakop**
Robberg Nature Reserve																	✓
Slootjies								✓									
unknown							✓	✓			✓						✓
Cape St Francis to Cape Padrone all		✓					✓										
Cape Recife		✓															
Van Stadens River		✓															
unknown							✓										
East of Cape Padrone all																	

Appendix 7. Description of how MARK software can be used for future analyses of movement patterns

The situation of uncertainty and data gaps experienced in determining the timing of the movement patterns of *H. moquini* is a common obstacle in capture-mark-recapture studies. A relatively new software package called MARK has been developed to deal with the situation. It develops a population or movement model based on the probability of resighting a bird in a given year. We are still the early stages of determining the oystercatchers' movement pattern, particularly since many of the sites used on the movement route were only located in 2004. At least five years' worth of data are generally required to get a good sense of movement patterns (G. Robertson, *pers. comm.*).

It is possible, however, to design future research and data collection plans around the possibility of using MARK software to develop a movement model for the species. MARK works best in situations where a lot of data are collected regularly at a few sites (G. Robertson, *pers. comm.*). What could be done, therefore, is the following:

- Divide the oystercatchers' movement route into three sections: local/short, medium, and long;
- Choose one or two sites from each of these three sections to sample intensively, and several times a year for several years;
- Collect data as per the following sample format, where 0 = not seen, 1 = seen at natal site, 2 = seen in local section, 3 = seen in medium section and 4 = seen in long section:

Bird band number	2006	2007	2008	2009	2010
UU1	1	2	3	3	2
UU2	1	0	0	4	4
UU3	1	0	0	0	0

- Adapt previous years' data to fit this format;
- Incorporate this dataset into MARK.

Appendix 8. Characteristics of roost sites and sites without roosts (data from 2004, except mollusc data from Wieters and Branch, unpublished data)

Location (from south to north, solid line indicates border between South Africa and Namibia)	**Latitude (degrees south and decimals)**	**Max. known roost size** (No. of birds)	**Roost presence / absence**	**Distance to nearest roost (km)**	**Exposure to waves 0 = sheltered; 1 = semi-sheltered; 2 = exposed**	**Sand**	**Rock**	**Slope (0=flat, 3=steep)**	**Promontory present? 0 = no; 1= yes**	**Proximity of river mouth (km)**	**Maximum angle of roost (degrees)**	**Per cent cover of *M. galloprovincialis* (zone 3)**	**Per cent cover *Aulacomya* (zone 3)**	**No. of *S. granularis per 0.25 m²* (zone 3)**	**Per cent cover of *M. galloprovincialis* (zone 4)**	**Per cent cover *Aulacomya* (zone 4)**	**No. of *S. granularis per 0.25 m² quad* (zone 4)**	**M. galloprovincialis biomass (g per 10 x 10 cm of mussel bed)**
Koeberg	33.6799	60	1	19	0	0	1	3	0	5	180							
	33.6667	0	0	1	2	1	0		0	6	180							
Bokpunt	33.5260	0	0	3	0	1	1		0	1	180	4.47	0.00	7.94	0.75	0.00	18.95	2.9882
	33.5000	0	0	23	1	1	1		1	2	240							
Yzerfontein	33.3571	54	1	31	1	0	1	2	1	9	240	69.05	0.00	31.20	0.32	0.00	16.64	5.4127
	33.3333	0	0	4	2	1	0		0	14	180							
	33.1667	0	0	5	1	1	1		1	28	315							
Kleineiland	33.1548	67	1	14	0	1	1	1	1	13	180	76.60	0.15	21.70	0.35	0.00	35.00	
	33.0000	0	0	3	0	1	1		1	21	315							
Mauritz Bay+ Hospital Point	32.9750	53	1	10	0	1	1	1	1	33	360							
	32.8333	0	0	1	0	1	1		1	7	337							
Shell Bay	32.7037	33	1	9	0	1	1	0	1	23	180							
Varkvlei	32.7831	53	1	8	1	1	0	1	1	0	360							
	32.6667	0	0	19	2	1	0		0	16	180							
	32.5000	0	0	22	2	1	0		0	24	180							
	32.3333	0	0	4	0	1	1		0	4	240							
Elands Bay+ Baboon Point	32.3172	81	1	60	0	1	1	1	1	1	240	1.06		16.50	0.20	0.00	10.60	
	32.1667	0	0	17	1	1	1		0	4	180							
	32.0000	0	0	36	0	1	1		0	10	240							
	31.8333	0	0	16	0	1	1		1	8	300							
Olifants River	31.6920	92	1	55	0	1	1	0	1	0	240							
	31.6667	0	0	4	2	1	1		0	4	180							
Namaqua Sands	31.6000	0	0	12	0	1	1		1	12	270	65.00	0.00	83.40	0.60	0.00	57.80	
	31.5000	0	0	26	0	1	1		1	8	270							
	31.3333	0	0	4	0	1	1		1	4	300							
Brand se Baai + Blinkwater Bay	31.2900	11	1	12	0	1	1	0	1	6	240							
Malkopbaai	31.2222	37	1	12	0	1	1	0	1	3	210							
	31.1667	0	0	7	0	1	1		0	6	180							
	31.0000	0	0	12	1	1	1		1	4	315							
Caravans	30.9500	0	0	5	1	1	1		0	13	180	58.20	0.55	69.95	0.53	0.00	44.85	2.3633
Outhouse etc.	30.9400	0	0	4	1	1	1		0	13	180	64.52	0.06	17.98	3.65	0.03	39.40	2.3000
Island Point	30.9160	26	1	31	0	0	1	2	0	9	360	63.80	1.96	43.53	2.64	0.02	54.64	0.7300
Groen River Lighthouse	30.8550	0	0	8	2	0	1		0	1	240	68.00	0.00	80.15	5.10	0.00	151.80	
	30.8333	0	0	9	2	1	1		0	1	200							

Location (from south to north, solid line indicates border between South Africa and Namibia)	**Latitude (degrees south and decimals)**	**Max. known roost size** (No. of birds)	**Roost presence / absence**	**Distance to nearest roost (km)**	**Exposure to waves 0 = sheltered; 1 = semi-sheltered; 2 = exposed**	**Sand**	**Rock**	**Slope (0=flat, 3=steep)**	**Prom-ontory present? 0 = no; 1= yes**	**Proximity of river mouth (km)**	**Maximum angle of roost (degrees)**	**Per cent cover of *M. gallo-provincialis* (zone 3)**	**Per cent cover Aula-comya (zone 3)**	**No. of *S. granu-laris per 0.25 m^2* (zone 3)**	**Per cent cover of *M. gallo-provin-cialis* (zone 4)**	**Per cent cover Aula-comya (zone 4)**	**No. of *S. granularis per 0.25 m^2 quad* (zone 4)**	***M. gallo-provincialis* biomass (g per 10 x 10 cm of mussel bed)**
DeBeers Gate	30.8280	0	0	11	1	1	1		0	2	180	2.80	0.00	117.80				
Moonbays	30.8100	0	0	13	2	1	1		0	4	180	73.57	0.00	54.53	0	0	53.8	
Uilspieëlduin	30.6800	10	1	31	1	1	1		1	10	200							
	30.5000	0	0	20	0	1	1		1	4	300							
Hondeklipbaai	30.3373	10	1	10	0	1	1	1	1	7	240	54.42	2.63	80.77	4.38	0.06	58.50	2.3250
	30.1667	0	0	16	0	1	1		1	12	240							
	30.0000	0	0	27	0	1	1		0	32	200							
Brazils	29.9000	0	0	16	0	1	0		0	24	240	37.70	0.05	63.636	0.00	0.00	40.95	4.2625
	29.8333	0	0	8	0	1	0		0	17	240							
North Brazil	29.8140	0	0	7	0	1	0		0	16	240	48.28	47.06	41.69	0.00	0.00	23.00	
North of Witstrandjie	29.7645	7	1	58	2	1	0		0	8	180	38.60	0.40	30.00	0.65	0.10	56.30	2.7650
	29.6667	0	0	9	2	1	0		0	1	180							
	29.5000	0	0	25	1	1	0		0	22	240							
	29.3333	0	0	5	0	1	0		0	42	180							
McDougall's Bay	29.2890	35	1	55	0	1	1	1	1	43	360	64.70	1.20	141.60	0.88	0.00	27.88	2.1938
	29.1667	0	0	13	0	1	0		0	25	240							
	29.0000	0	0	35	0	1	1		0	3	200							
	28.8333	0	0	48	1	1	1		0	21	180							
	28.6667	0	0	26	0	1	1		0	6	180							
28°30-31'	28.5083	10	1	48	2	1	0		0	22	180							
	28.5000	0	0	1	1	1	0		0	23	180							
	28.3333	0	0	25	2	1	1		0	47	180							
	28.1667	0	0	5	2	1	0		0	73	180							
28°08'	28.1333	15	1	13	2	1	1		0	80	180							
28°03.20'	28.0533	7	1	13	2	1	0		0	92	180							
	28.0000	0	0	7	1	1	1		0	100	180							
Panther Head/Chameisbucht	27.9333	7	1	16	0	1	1		0	109	180							
	27.8333	0	0	12	2	1	1		0	124	180							
	27.6667	0	0	14	0	1	0		0	114	180							
Driemasterbaai	27.5333	18	1	16	0	1	1		0	96	300							
	27.5000	0	0	7	2	1	1		0	82	180							
Bogenfels Arch	27.4583	16	1	7	0	1	1		1	81	350							
	27.3333	0	0	6	2	1	1		0	57	200							
27°15.00'-16.80'	27.2650	11	1	5	2	0	1		0	58	200							
Pomona Island & vicinity	27.1917	90	1	4	1	0	1		1	49	360							
	27.1667	0	0	4	0	1	1		0	45	180							

Location (from south to north, solid line indicates border between South Africa and Namibia)	**Latitude (degrees south and decimals)**	**Max. known roost size** (No. of birds)	**Roost presence / absence**	**Distance to nearest roost (km)**	**Exposure to waves 0 = sheltered; 1 = semi-sheltered; 2 = exposed**	**Sand**	**Rock**	**Slope (0=flat, 3=steep)**	**Promontory present? 0 = no; 1= yes**	**Proximity of river mouth (km)**	**Maximum angle of roost (degrees)**	**Per cent cover of *M. galloprovincialis* (zone 3)**	**Per cent cover Aulacomya (zone 3)**	**No. of *S. granularis per 0.25 m²* (zone 3)**	**Per cent cover of *M. galloprovincialis* (zone 4)**	**Per cent cover Aulacomya (zone 4)**	**No. of *S. granularis per 0.25 m² quad* (zone 4)**	**M. galloprovincialis biomass (g per 10 x 10 cm of mussel bed)**
South of Possession Island	27.0407	20	1	9	2	0	1		0	30	200							
	27.0000	0	0	3	2	1	1		0	27	200							
Elizabeth Bay area	26.9328	100	1	17	0	1	1		0	15	240							
	26.8333	0	0	3	2	1	1		0	27	200							
	26.6667	0	0	2	0	1	1		1	18	240							
Lüderitz area	26.6250	147	1	23	0	1	1		1	16	240							
	26.5000	0	0	11	0	1	0		0	4	270							
	26.3333	0	0	4	0	1	1		1	32	330							
Douglas Pt. to Ichaboe Island	26.3143	104	1	20	0	1	1		1	35	330							
	26.1667	0	0	5	0	1	1		0	52	300							
Hottentot's Pt.	26.1458	111	1	10	0	1	1		0	57	300							
Black Rock	26.0850	9	1	8	1	1	1		0	67	270							
Gibraltar	26.0117	13	1	8	1	1	1		0	75	270							
	26.0000	0	0	1	2	1	0		0	77	180							
No name	25.8717	14	1	14	1	1	0		0	92	270							
	25.8333	0	0	7	2	1	0		0	99	180							
Clara Hill	25.7750	20	1	15	1	1	0		0	118	240							
	25.6667	0	0	5	2	1	0		0	121	240							
N of Arkona	25.5550	19	1	27	1	1	0		0	143	240							
	25.5000	0	0	1	2	1	0		0	141	180							
	25.3333	0	0	4	2	1	0		0	160	180							
Easter Point	25.2867	16	1	32	0	1	0		1	168	270							
	25.1667	0	0	16	2	1	0		0	180	180							
	25.0000	0	0	34	2	1	0		0	199	180							
	24.8333	0	0	54	2	1	0		0	220	180							
	24.6667	0	0	75	2	1	0		0	240	180							
	24.5000	0	0	97	2	1	0		0	238	180							
	24.3333	0	0	114	2	1	0		0	217	180							
	24.1667	0	0	94	2	1	0		0	198	180							
	24.0000	0	0	76	2	1	0		0	180	180							
	23.8333	0	0	56	2	1	0		0	161	180							
	23.6667	0	0	37	2	1	0		0	142	225							
	23.5000	0	0	17	2	1	0		0	122	180							
Sandwich Harbour	23.3720	38	1	48	0	1	0		1	62	360							
	23.3333	0	0	4	2	1	0		0	102	180							
	23.1667	0	0	24	2	1	0		0	83	180							

Location (from south to north, solid line indicates border between South Africa and Namibia)	Latitude (degrees south and decimals)	Max. known roost size (No. of birds)	Roost presence / absence	Distance to nearest roost (km)	Exposure to waves 0 = sheltered; 1 = semi-sheltered; 2 = exposed	Sand	Rock	Slope (0=flat, 3=steep)	Prom-ontory present? 0 = no; 1= yes	Proximity of river mouth (km)	Maximum angle of roost (degrees)	Per cent cover of *M. gallo-provincialis* (zone 3)	Per cent cover Aula-comya (zone 3)	No. of *S. granu-laris per 0.25 m²* (zone 3)	Per cent cover of *M. gallo-provin-cialis* (zone 4)	Per cent cover Aula-comya (zone 4)	No. of *S. granularis per 0.25 m² quad* (zone 4)	M. gallo-provincialis biomass (g per 10 x 10 cm of mussel bed)
	23.0000	0	0	7	0	1	0		0	63	180							
Walvis Bay	22.9667	160	1	50	0	1	0		0	39	180							
	22.8333	0	0	21	2	1	0		0	17	180							
	22.6667	0	0	8	2	1	1		0	1	250							
Swakopmund	22.5833	60	1	50	1	1	1		0	3	200							
	22.5000	0	0	10	2	1	1		0	19	180							
	22.3333	0	0	19	2	1	1		0	1	180							
	22.1667	0	0	61	1	1	0		0	1	180							
Cape Cross Bay	21.7500	12	1	113	0	1	1		0	0	200							
	21.6667	0	0	10	2	1	0		0	20	180							
	21.5000	0	0	31	2	1	0		0	43	180							
	21.3333	0	0	51	2	1	0		0	20	180							
	21.166666	0	0	75	2	1	1		0	4	180							
	21	0	0	96	2	1	1		0	1	180							
	20.666666	0	0	137	2	1	1		0	21	180							
	20.5	0	0	132	2	0	1		0	1	180							
	20.3333	0	0	113	1	1	1		0	18	180							
	20.166666	0	0	92	1	1	1		0	2	180							
	20	0	0	69	1	1	1		0	15	180							
	19.8333	0	0	48	2	0	1		0	5	180							
	19.666666	0	0	28	2	1	1		0	23	180							
Hoanibmond	19.4750	35	1	290	0	1	1		0	5	180							
	19.3333	0	0	12	2	1	0		0	17	180							
	19.1667	0	0	33	2	1	1		0	11	180							
	19.0000	0	0	58	1	1	1		0	11	360							
	18.8333	0	0	79	1	1	0		0	32	180							
	18.6667	0	0	103	2	1	0		0	56	180							
	18.5000	0	0	131	2	1	1		0	84	180							
	18.3333	0	0	151	2	1	1		0	104	180							
	18.1667	0	0	173	2	1	0		0	104	180							
	18.0000	0	0	191	2	1	0		0	84	180							
	17.8333	0	0	172	2	1	0		0	65	180							
	17.6667	0	0	153	2	1	1		0	46	180							
	17.5000	0	0	135	2	1	1		0	27	180							
	17.3333	0	0	116	2	1	1		0	8	180							

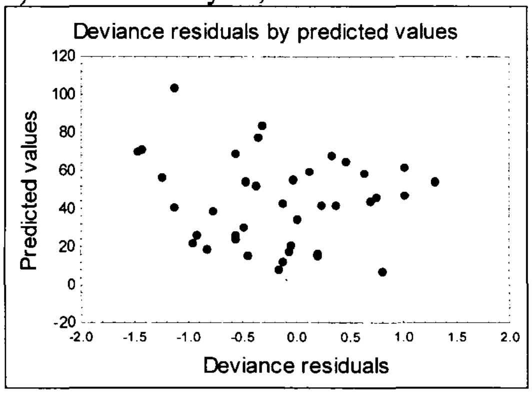
Appendix 9. Supplementary information for data analyses

a) Correlation analysis of habitat variables (cells contain Pearson correlation coefficients; significant correlations are shaded)

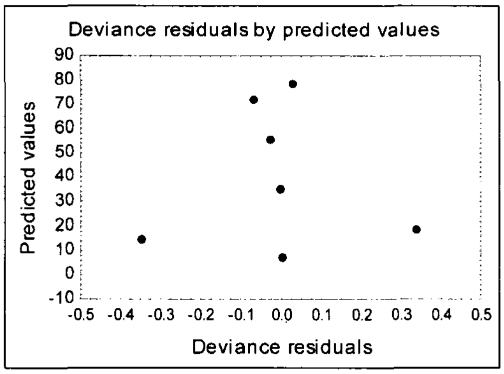
	Latitude	Max. roost size	Roost presence/ absence	Dis-tance to nearest roost	Exposure	sand	rock	# of sub-strates (rock, sand)	Promon-tory?	Proximity of river mouth	Max. angle of roost	Slope	% M. gallo-provincialis zone 3	% A. ater zone 3	# .S. granu-laris zone 3	% M. gallo-provincialis zone 4	% A. ater zone 4	No.S. granu-laris zone 4
Max.roost size	0.125																	
Roost presence/ absence	0.199	0.678																
Distance to nearest roost	-0.640	-0.032	-0.051															
Exposure	-0.451	-0.383	-0.376	0.220														
sand	-0.070	-0.157	-0.228	0.025	-0.053													
rock	0.193	0.159	0.169	-0.030	-0.315	-0.209												
# of substrates	0.165	0.079	0.054	-0.021	-0.303	0.286	0.848											
Promontory?	0.434	0.347	0.361	-0.199	-0.525	-0.001	0.319	0.312										
Proximity of river	-0.263	-0.128	-0.052	0.125	0.333	0.134	-0.493	-0.412	-0.230									
Max.angle of roost	0.313	0.295	0.355	-0.263	-0.542	-0.098	0.241	0.183	0.630	-0.164								
Slope	0.350	0.072	0.000	-0.006	0.016	-0.800	0.173	-0.631	-0.749	0.086	0.072							
% M. galloprovin-cialis zone 3	-0.132	-0.015	0.113	-0.169	0.115	-0.339	0.153	-0.150	0.178	0.340	0.246	0.278						
% A. ater zone 3	-0.286	-0.157	-0.179	-0.166	-0.240	0.127	-0.525	-0.326	-0.171	0.125	0.082	0.003	-0.042					
# .S. granularis zone 3	-0.568	-0.272	-0.101	0.025	0.004	0.063	0.148	0.170	0.130	0.467	0.412	-0.112	0.111	-0.111				
% M. gallo-provincialis zone 4	-0.177	-0.254	0.005	-0.267	0.211	-0.407	0.337	-0.057	-0.106	-0.233	0.141	0.136	0.251	-0.204	0.179			
% A. ater zone 4	-0.364	-0.185	0.388	0.307	0.321	0.130	-0.342	-0.173	-0.116	-0.147	-0.168	0.014	-0.073	-0.117	-0.120	0.298		
No. S. granu-laris zone 4	-0.276	-0.416	-0.259	-0.258	0.565	-0.439	0.092	-0.284	-0.294	-0.262	0.031	0.117	0.384	-0.222	0.338	0.684	0.128	
M. galloprovin-cialis biomass	0.413	0.283	-0.116	-0.030	0.030	-0.108	-0.296	-0.338	0.277	-0.027	-0.349	0.238	-0.122	-0.615	-0.198	-0.549	-0.242	-0.580

b) Plots of deviance residuals versus predicted values for gamma regression comparing maximum roost size with presence of certain habitat characteristics

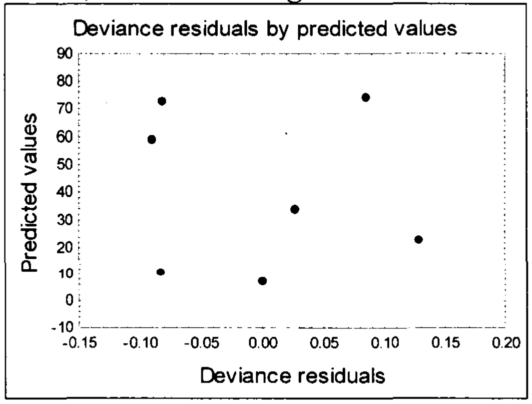
a) For first analysis, maximum roost size vs. physical habitat variables:



b) For second analysis, maximum roost size vs. proximity of river mouth, exposure to wave action, percent mussel cover in intertidal zone 3 and numbers of *S. granularis* in intertidal zone 4:



c) For third analysis, maximum roost size vs. proximity of river mouth, exposure to wave action, numbers of *S. granularis* in intertidal zones 3 and 4:



Appendix 10. More details on marine protected areas in South Africa and Namibia

South Africa has more marine reserves than any other African country (Hockey and Branch 1997). All MPAs in South Africa run along the coast of the mainland, and cover a total of 17% of the South African coastline. MPAs are evenly distributed around the coastline except in Northern Cape Province, which lacks adequate representation. Western South Africa (Western and Northern Cape) includes 6 marine reserves, 8 general restricted areas, 6 single species restricted areas, 3 national parks, and 6 estuarine protected areas; 4 are no-take areas, and the 3 national parks (terrestrial) are zoned for multiple use. All but 2 are in the Western Cape (Attwood *et al.* 1997, Attwood *et al.* 2000).

Marine protected areas in South Africa were largely established in an *ad hoc* fashion, and therefore do not necessarily adequately represent the ecosystems that must be prioritized for conservation. Furthermore, marine and terrestrial protection strategies are not adequately linked. Management of protected areas comes under several different government departments at all levels (national, provincial, local). There is inadequate funding for enforcement, monitoring, community involvement and education regarding marine protected areas on the west coast (Hockey and Buxton 1989, Attwood *et al.* 1997, Hockey and Branch 1997, Attwood *et al.* 2000, Wynberg 2000).

Namibia has one of the longest protected coastlines in the world. The whole coastal area from the Iona National Park in southwestern Angola to the Ramsar site on the Namibia-South Africa border is protected, except for the Sperrgebiet and the Swakopmund-Walvis Bay area. Between the mining area and the farms of southern Namibia, however, exists a largely undisturbed area which makes up over 90% of the total Sperggebiet area. Ichaboe island, Lüderitz Bay and lagoon, and the Orange River mouth wetlands, which are all adjacent to the Sperrgebiet, are proposed marine reserves. There is a proposal to proclaim the Sperrgebiet as a multi-use zoned National Park. Large parts of the area were deproclaimed from exclusive diamond prospecting and mining, returning the land to unproclaimed state land status. All offshore islands in the Sperrgebiet are nature reserves, as many are seal and seabird breeding areas. Because of the high economic importance of the diamond mining industry to the Namibian economy, however, mining activities will continue along the coast (Pallett 1995, WSP Walmsley no date).

Appendix 11. More details on the diamond mining process

Diamonds are one of South Africa's chief exports. Diamonds were discovered in 1867 along the Vaal and Orange rivers and in 1870 at what became Kimberley, the capital of Northern Cape province. Coastal diamond mining takes place in South Africa from Alexander Bay to past Kleinsee. Gold was discovered in 1886 on the Witwatersrand. Mining then became the foundation for rapid economic development. South Africa is a world leader in the production of gold, diamonds, aluminosilicates, chromium, manganese, vanadium, and platinum. Other leading minerals extracted are copper ore, coal, asbestos, iron ore, silver, uranium and titanium ("South Africa" 2003, Pallett 1995).

Southern Namibia also contains rich diamond deposits in gravel beds, formed over the last 2 million years when the sea level was higher. The diamond deposits are concentrated in an area 3 km wide and stretching for 100 km along the coast northward from Oranjemund. Diamond Area number 1 has been closed to the public since 1908, and is still under extremely high security. In 1928, extensive diamond deposits were found in ancient marine terraces north of the Orange River mouth. Large scale production started in 1935 and increased in the 1940s after the Depression. The diamond mines are now controlled by NAMDEB, which holds prospecting and mining licenses in a portion of the area; the remainder is controlled by the Namibian Ministry of Mines and Energy. The actual mine operations are carried out by smaller companies under contract. The coast of Namibia from Lüderitz to the Orange River, and up the river for about 100 km is intensively mined, including both terrestrial and marine regions. Shallow-water diamond mining is carried out from shore as well as from nearshore vessels. Deep water mining from 5 to 40 km offshore and up to 100 m deep is conducted by De Beers Marine

(Pty) Ltd under contract to NAMDEB, using boats that pump the sandy gravel from the ocean floor. Deep water mining started in 1991 and has since increased (Pallett 1995).

In nearshore areas, usually in sheltered areas, diamonds are extracted to a depth of 0-10 m by divers carrying hoses with a diameter of 200 mm and attached to a suction pump. The hose and pump are attached to a modified tractor, which drives a rotary classifier and the pump. The divers guide the hoses to suck up gravel deposits, which are then sent to the classifier (Pulfrich *et al.* 2003a).

Terrestrial diamond mining is open-cast and involves removal of millions of tons of overburden per month, including sand dunes, to access diamondiferous deposits in gravel beds up to 20 m below sea level. The ore in gullies and potholes is excavated manually with suction equipment and brooms, then taken to treatment plants where gravel is crushed, screened and concentrated using water and ferrosilicone; most of the latter is recycled. The waste gravel is piled in tailings dumps (Pulfrich *et al.* 2003b).

Mining in the Namibian diamond area was expected to decrease in the first quarter of the present century, with the emphasis being changed to re-treatment of tailings dumps, plus small-scale mining in the nothern Sperrgebiet, along the Orange River and at Elizabeth Bay. Offshore mining was also expected to increase (Pallett 1995).

About 70 diamond pumping units were operating in 1992 between the mouths of the Olifants and Orange Rivers in South Africa, working about 100 days per year. In one year they may cover 0.7 km^2, or 4.5% of the total rocky reef area (Barkai and Bergh 1992). Exploration and mining by DeBeers in the coastal and intertidal areas of the west coast at the time of writing is limited to a prospecting unit at Brand se Baai and two diving units north of Kleinsee. A few of the Koingnaas mining blocks are adjacent to the coastal strip but in Kleinsee most of the activity is two to four kilometres inland. There is some beach mining in various locations north of Koingnaas (DeBeers, *pers. comm.*).

Appendix 12. Reporting violations of the coastal ban on off-road vehicles

There is a toll-free telephone number (0800-116-110) to report environmental violations to the Department of Environmental Affairs and Tourism (DEAT). I called this number on 17 February 2005 to report the license plates the two vehicles I had observed driving on the beaches at Elands Bay and Olifants River. The service is called 'Tip-Offs Anonymous'; the recorded message stated that with the information that people provide, "specialist investigators prepare and send a formal tip-off report to independent, designated persons to authorize appropriate follow-up actions". The agent with whom I spoke stated that with the information provided by me, he would compile a report for DEAT. He stated that they often receive calls regarding issues such as dumping and pollution, however this is the first time he had received a call regarding cars observed driving on beaches. Given that cars do still drive on at least some beaches, one can conclude that there is likely little awareness or use of this method of vigilance.

Appendix 13. Useful contacts

Access:

West Coast National Park (Kleineiland):
- Pierre Nel, West Coast National Park: 022-772-2144, 082-470-4982, pierren@parks-sa.co.za

Varkvlei:
- Zirk (farm foreman): 072-915-7977 (?)
- Andrew Tredoux (adjacent farmer): 022-783-0805

Transhex:
- Michele and Peter Slott-Nielson: petersn@transhex.co.za; 027-217-1157; 083-632-2205
- Wynand Wickens (to facilitate access to Olifants River mouth): 027-217-1790 or 083-711-8785

Namaqualand Mines (DeBeers), Kleinsee:
- Paul Kruger, Environmental Officer: 027-807-3250, paul.kruger@debeersgroup.com
- Jenny van der Westhuizen, Environmental Officer: jenny.vanderwesthuizen@debeersgroup.com
- Elitha Pieterse, Access Control: 027-807-3602, elitha.pieterse@debeersgroup.com
- Elmien Ballot: 027-807-3205; elmien.ballot@debeersgroup.com
- Deon Erasmus, Security Manager: 027-807-3601, deon.erasmus@debeersgroup.com
- Patti Wickens, Environmental Officer in Cape Town: 021-409-7222, 083-448-2279

Namakwa Sands:
- Torsten Halbich: thalbich@namakwa.co.za

Alexkor:
- Elizma Boonzaaier: 027-831-1330, elizma@alexkor.co.za
- Environmental Officer: Philip Setzer (Surveyor); 027-831-1330; philips@alexkor.co.za (very helpful)
- Dave Eshmade, Head of Department, Emergency and Protection: 027-831-1330

Namdeb:
- Fiona Olivier, Environmental Management Coordinator, Box 253, Oranjemund, Namibia; tel (+264 63) 235689; fax (+264 63) 235460; fiona.olivier@namdeb.com
- Peter Shout, Security Department: peter.shout@namdeb.com
- Jackie Matthee, Security Secretary: (+264 63) 236001 or 236000
- Esther Auala, Airport Logistics Clerk: (+264 63) 235906

Accommodation:

- Marcus Island, free house: Pierre Nel, West Coast National Park: 022-772-2144, 082-470-4982, pierren@parks-sa.co.za
- Jacobsbaai: R120/day; 083-270-3062

Elands Bay:

- Hotel Eland (has backpackers hostel and campsites as well as hotel and restaurant): 022-972-1640

Olifants River:

- Free camping with facilities at an old San cave on property owned by Wynand Wickens, a man who is very interested in oystercatchers, near Koekenaap: 027-217-1790 or 083-711-8785

Brand se Baai to Island Point:

- Free camping at designated campsites along the coast; there is a campsite right next to the Island Point roost
- Joetsies (?) in Komkans, don't know the phone number
- Soutklip farm, Coria Nieuwoudt - 027-531-1037; R120, a bit far from the coast but the owners are helpful; must get petrol in Kotzesrus or Garies, or take jerry cans; directions: through Lutzville, through Koekenaap, past Nuwerus sign, at Komkans sign turn right onto gravel road, 1/2 hour is Katdoringvlei, go straight, go right at gate (don't go through gate), pass Lepelfontein, on right side see sign for Soutklip
- Groenriviermond - there was a mining community there; perhaps there are still tents or houses that are accessible? Must contact DeBeers, perhaps via contractors Stephen/Tracy Browne 082-443-4882

Springbok:

- Springbok Lodge: 027-712-1321

Hondeklipbaai:

- Camping - open access; for keys to toilets, call Elizabeth at 027-692-3066
- Die Honnehok guest house - 027-692-3041; cheaper rates available off season, owners know oystercatcher project and are helpful

McDougall's Bay:

- Caravan park (with serviced campsites and indoor accommodation) - 027-851-1111 (R79 to camp or R131 for the "igloo")

Alexander Bay:

- Alexander Bay Guesthouse: 027-831-1330 ext. 2234 (must contact Alexkor first and go through them)

Car repair:
- Bitterfontein: Nico Boonzaaier - 027-642-7217, 027-642-7128
- Port Nolloth: 082-259-7297

Interested individuals:
Koeberg:
- Nola Parsons, student of Professor Les Underhill, Avian Demography Unit, University of Cape Town: nola@sanccob.co.za

McDougall's Bay:
- Jimmy du Toit, boat access?: 082-894-6638

Sandwich Harbour:
- Mark Boormann: +264-64-405146; felix@mweb.com.na

Pilots:
- Tammo von Eck, Good Hope Flying Club: 021-423-8233, 084-350-0488, tammo@mweb.co.za
- Rod Braby, Windhoek, Namibia: iczmenv@iafrica.com.na

Mussels:
- George Branch: gmbranch@botzoo.uct.ac.za
- Tammy Robinson: trobins@botzoo.uct.ac.za; 021-650-3610 (Charles Griffiths lab)
- Evie Wieters: ewieters@genes.bio.puc.cl; +56-35-43167

Diamond mining:

Research: Andrea Pulfrich - apulfrich@pisces.co.za

Transhex
Me Babalwa Mbalo: (021) 937 2000 w; (021) 937 2100 fax

Namaqualand Mines
Paul Kruger, Environmental Officer: 027-807-3250, paul.kruger@debeersgroup.com

Namakwa Sands
Theresa Steele: (027) 217 3164; 027 2173095 or 027 2173050 or 027 2173100
(027) 217 3301 /3055 fax; tsteele@namakwa.co.za

Alexkor (Alexander Bay)
Environmental Officer: Philip Setzer (Surveyor); 027-831-1330; philips@alexkor.co.za

Developments
Jeremy Benjamin, Town Planner, Saldanha Municipality: (022) 701 7058

Kelp harvesting:

Dr. Rob Anderson, Botany Dept, UCT: anderson@botzoo.uct.ac.za; (021) 650 3717

Marine and Coastal Management:

Dr Rob Crawford	Me. Dandy Reynolds
(021) 402 3140	(021) 402 3194 w
(021) 421 7406	(021) 402 3194 fax
Crawford@deat.gov.za	Reynolds@deat.gov.za

FAMDA:
Mr. Denver Baron
(027) 851 8430 w
(027) 851 8432 fax
famda@telkomsa.net

National Parks:
- Pierre Nel, West Coast National Park: 022-772-2144, 082-470-4982, pierren@parks-sa.co.za
- Colin Attwood, Marine and Coastal Management: 021-402-3190; cattwood@deat.gov.za
- Mr. Giel de Kock, SANParks: (027) 672 1948 emmerentiadk@parks-sa.co.za

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