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Declining coastal avifauna at a diamond-mining site in Namibia: comparisons and causes

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A review of Namibian shorebird densities over two decades and two additional visits to the coastal diamond-mining areas at Elizabeth Bay, southern Namibia, were undertaken to assess the long-term influence of mining activity on density of shorebirds (Charadrii) and particularly threatened African Black Oystercatchers *Haematopus moquini* and Damara Terns *Sterna baleanarum*. Oystercatcher numbers remained relatively stable over 25 years, with some recent declines relative to previous surveys along the beach, while that of other shorebirds showed dramatic declines. Density of shorebirds fell 4.3-fold from 220 birds/km to 41 birds/km, relative to similar (pre-mining) surveys 25 years previously. Over the last nine years birds have declined from 12 to nine species. Control sites on nearby sandy beaches over the same (nine-year) period showed no such declines. From the mid-1970s (pre-mining), Damara Terns also declined from 20 breeding pairs to 2–7 breeding pairs between 1996 and 2002; they have remained stable elsewhere in Namibia. Mining activity does not directly impact the known tern nesting sites, but reduced tern numbers have occurred since 1.5 million m^3 of fine sediments have been deposited annually into the bay. Observed foraging success of terns at Elizabeth Bay in 2002 was lower than recorded elsewhere in southern Africa, and independent data indicates that the abundance and biomass of their surf zone fish prey is lower in Elizabeth Bay than the nearest control site. Fish availability may also be reduced because most fish occurred within the sediment plume. The decline of the mollusc-eating component of shorebirds can also be explained by the disappearance of the White Mussel and other shellfish favoured by oystercatchers. I conclude that releasing sediment into the bay is detrimental to coastal avifauna and simple conservation measures are given that could reverse and allow further (experimental) study of the reasons for the trends found.

Introduction

Mining activity is often vital to a country's economy and in Namibia mining contributes about 12–15% of the current Gross Domestic Product (Mendelsohn *et al.* 2002). Most diamond mining activity is concentrated around the Orange River mouth in Namibia, where diamonds were brought from the interior by the river and spread north by the Benguela Current (Pallet 1995, Tarr 2003). The Sperrgebiet (forbidden area) covers the most important diamondiferous areas along the south-western coast of Namibia, from Oranjemund to Lüderitz (c. 300km long and 100km wide), and has been mined intensively for diamonds since 1907, following their discovery (Pallet 1995).

The south-western shores of Africa also hold some of the highest densities of shorebirds (Charadrii) anywhere (Hockey *et al.* 1992), reaching peak densities on the central Namibian coast (Simmons and Cordes 2000). The mix of high shorebird density and intense diamond mining close to the bird's foraging habitat has rarely been investigated because of the inaccessibility and security surrounding diamond-bearing sites (Maartens 2003). While the security measures have protected large areas of the Succulent Karoo biome they have also reduced the repeatability of surveys, making robust long-term conclusions of any impact difficult.

The few published studies that exist of the impacts of coastal mining on biodiversity indicate that some communities can return to their pre-mined diversity, e.g. on coastal dunes in South Africa (Mentis and Ellery 1998), among inter-tidal communities near diamond mines off south-western Africa (Pulfrich *et al.* 2002a, 2002b), and benthic communities off the Namibian coast (Griffiths *et al*. 2004). None of these papers, however, considered the impacts on avifauna, despite the warnings by Connor (1980) that mining will probably impact coastal breeding birds, particularly Damara Terns (*Sterna balaenarum*). This paper reports findings from four studies of the coastal avifauna in one of the few sheltered bays (or pocket beaches) at Elizabeth Bay, in the Sperrgebiet. This site was chosen because of its proximity to a large open-cast diamond mine just inland at Elizabeth Bay, intermittently operational from 1911–1948 and restarted again in 1991 (Pallett 1995). It was also the site of three earlier studies, the first by Whitelaw *et al.* (1978), followed by Velasquez *et al.* (1993), on shorebirds of the Elizabeth Bay beach, allowing a 25- and nine-year time-series of shorebird numbers there. The third was a series of surveys by Johnson (1979) of breeding Damara Terns *Sterna balaenarum*, a globally threatened Red Data species (Barnes 2000, Birdlife International 2004, Simmons and Brown 2005). These studies allow a 25- to 30-year time-series assessment that includes before-and-after mining comparison of shorebird and Damara Tern population trends and insights into the effects of diamond mining on the beach avifauna. This is the first published study of the effects of diamond mining on birds in southern Africa, and the first to use pre-mining data for comparison.

Study area

Elizabeth Bay (26.9°S, 15.2°E) lies 30km south of Lüderitz, southern Namibia, and is the largest sheltered bay in the Sperrgebiet (Pallet 1995). The Sperrgebeit is a pristine Succulent Karoo wilderness proposed as a future national park by Namibia's Ministry of Environment and Tourism (Barnard 1998, *et al.* 1998). It lies within the hyper-arid Namib Desert with a cool climate (10–20°C), an average (winter) rainfall less than 20mm per year, and high variability (Mendelsohn *et al.* 2002). The bay itself comprises a 5.3km-long curved sandy beach bounded at each end by rocky shores, and inland (north) by vegetated dune hummocks. The beach is estimated to have prograded more than 200m into the sea in three years (Pallett 1995) and is now more than 500m larger than it was in 1975 (RE Simmons pers. obs.). This occurs as fine sediment from the mining process (hereafter referred to as 'fines'), washed with sea water and introduced into the bay in the form of a slurry, settles out on the previous beach (Pallet 1995, CSIR 2002). All previous surveys were undertaken between November and January because this is peak Damara Tern breeding season (Simmons and Braine 1994, Braby *et al.* 2002) and the season for peak shorebird numbers in southern Africa when Palearctic migrants are then present and stable in numbers (Tarr and Tarr 1987, Spearpoint *et al.* 1988, Hockey and Douie 1995).

Methods

I spent three days (21–23 November 2002) in the Elizabeth Bay mining areas, accompanied by the mining company's (Namdeb) land surveyor, travelling through intended mine sites and possible Damara Tern breeding areas on the gravel plains 3–4km inland of the coast. One day was spent surveying the bay environs, measuring shorebird density by counting all shorebirds at low tide along the beach, while moving slowly on a three-wheel motorbike. Shorebird numbers were divided by the length of the beach, to generate bird density/km of beach. Distances were gauged using the motorbike's odometer, accurate to 10m. All observations of birds and of Damara Tern foraging bouts over water were made with 8 x 30 binoculars, and distances measured from the outlet pipe (centrally placed along the beach) with a Garmin II GPS. Tern foraging bouts (dives and successful dives per minute of hover-foraging) were timed using a stopwatch and written in a pocket notebook. Previous surveys in 1996 (Simmons and Cordes MS) were undertaken along the same 5.3km stretch of beach, and (for breeding Damara Terns) by intensively searching the gravel plains inland of the bay using the same methodology. Two earlier studies, pre-mining (<1991) (Whitelaw *et al.* 1978) and post-mining (Velasquez *et al.* 1993), were undertaken by experienced ornithologists from the University of Cape Town covering the same stretch of beach in November 1993. In 1977, however, the beach length monitored was only 3.0km (Whitelaw *et al.* 1978). This curious reduction probably arose because the beach had not prograded before 1991, and the rocky boundaries were probably closer together (and are now covered by introduced sand).

The nearest control area where shorebirds have been monitored — on a south-facing sandy embayment bounded by rocky shores — occurs at Grosse Bucht c. 19km north of Elizabeth Bay. Wetland counts along the 1.4km beach at this site, by I Cordes, H Kolberg and myself between 1992 and 2002, were extracted from Jarvis *et al.* (2001). Rocky shores were not used as comparisons because they hold different densities and species of shorebirds (Tarr and Tarr 1987; see Discussion). This small sandy beach was also used as a control site for Elizabeth Bay inter-tidal studies by McLachlan *et al.* (1994) and for surf-zone fish communities by Clarke *et al.* (1998).

Results

Shorebird density

During the 2002 survey, 215 shorebirds occurred along the 5.3km Elizabeth Bay beach at a density of 41 birds/km. Densities of 101 birds/km were recorded in 1996 (Simmons and Cordes MS), 156 birds/km in 1993 (Velasquez *et al.* 1993) and 220 birds/km from 1977 (Whitelaw *et al.* 1978). This represents a steady 4.3-fold decline in density over a 25-year period (Figure 1) covering the period pre-mining to post-mining. The difference was primarily due to a great decline in Turnstone (*Arenaria interpres*) numbers (Table 1) — a species that feeds on molluscs, and the Sanderling (*Calidris alba*), which declined from 400 birds in 1993 to 116 in 2002 (Table 1). Species richness did not concurrently decline but varied from six to 12 to nine over the same time period (Table 1).

Shorebird data (in Jarvis *et al.* 2001) from the control site at the 1.4km Grosse Bucht beach, which has never been mined, indicates slightly increasing shorebird num-

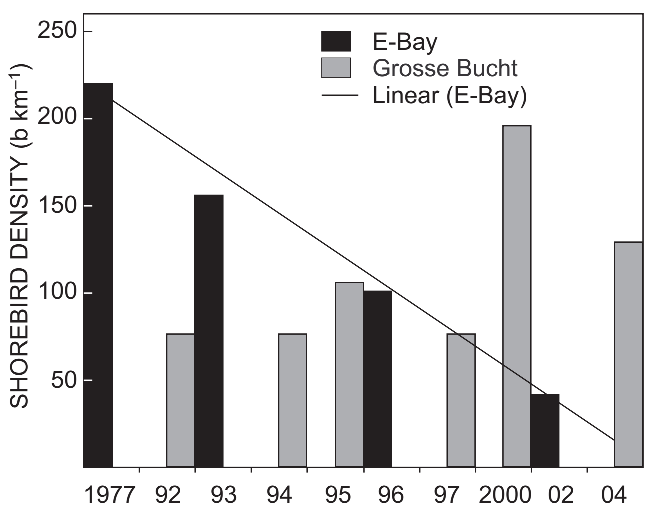

Figure 1: The declining density of shorebirds recorded along the Elizabeth Bay beach (1977–2002), compared with a control site at the similar Grosse Bucht beach, (19km north of Elizabeth Bay). Diamond mining began at Elizabeth Bay in 1991.

Table 1: A comparison of numbers of all shorebird species recorded from 1977, 1993, 1996 and 2002 surveys of the Elizabeth Bay beach (5.3km long). Declining trends were apparent in all species except Curlew Sandpipers

Species	1977[a]	1993[b]	1996[c]	2002[d]	Trend
African Black Oystercatcher *Haematopus moquini*	9	26	35	25	Stable
White-fronted Plover *Charadrius marginatus*	57	52	12	9	-ve
Sanderling *Calidris alba*	327	400	131	116	-ve
Curlew Sandpiper *Calidris ferruginea*	0	33	120	26	None
Little Stint *Calidris minuta*	0	2	0	0	–
Ruddy Turnstone *Arenaria interpres*	94	210	162	2	-ve
Red Knot *Calidris canuta*	0	0	6	0	–
Grey Plover *Pluvialis squatarola*	38	40	51	15	-ve
Ringed Plover *Charadrius hiaticula*	0	12	5	0	-ve
Damara Tern *Sterna balaenarum*	15–20 pr (1970s)[e]	Not recorded	2 pr	7 pr	-ve
Kelp Gull *Larus dominicanus*	136	42	8	12	-ve
Hartlaub's Gull *Larus hartlaubii*	0	0	0	2	–
Greater Flamingo *Phoenicopterus ruber*	0	3	0	0	–
Abundance:species	661:6	851:12	534:10	215:9	

[a] Whitelaw *et al*. 1978 in a 3km stretch of beach
[b] Velasquez *et al*. 1993
[c] Simmons and Cordes MS
[d] This study
[e] Johnson 1979

bers from five counts (1992–2004: Figure 1). The number of species over the same years was five, eight, six, 13, nine and eight, respectively.

Globally threatened species: Damara Terns and African Black Oystercatchers

Three pairs of Damara Terns were found breeding among barchan dunes on the gravel plains above the Elizabeth Bay Valley in 2002. Two were incubating single eggs, and one was brooding a single chick. Four already-flighted young that were fed small fish by adults, were found on the southern beach. The total breeding numbers for the area were thus at least seven pairs. In 1996, in one day's observation, two pairs and no fledglings were recorded in January. Both data sets indicate that Damara Tern populations are 2–3-fold lower than the 15–20 pairs found by Johnson (1979) in the mid-1970s, before the Elizabeth Bay mine came back into operation.

In 2002 twenty-five African Black Oystercatchers *Haematopus moquini* were found on rocky habitat at the southern end of the Elizabeth Bay beach. This compares with a total of 35 individuals from the 1996 survey — a 29% decline in six years. Similar numbers (26 individuals) were recorded in 1993 (Velasquez *et al.* 1993).

Damara Tern foraging success

In 2002, foraging terns at Elizabeth Bay moved to between 1.05km (two adults) to just over 3km to the south-east of the slurry pipe and plunge-dived either between the breakers or into shallow receding waves close inshore. Those birds closest to the pipe were never seen to catch fish, or even attempt to catch fish, in 5min observation of continuous foraging. Another group of 4–5 adult birds were timed foraging about 3.5km south-east from the pipe outlet and they were more successful. They dived at an average frequency of 0.71 dives/min (four dives in 5min). Of the 10 dives recorded in 19min 31sec of foraging, two dives were successful, at a rate of 0.10 fish/min of foraging.

Discussion

The main findings of this study are that most measures of shorebird abundance showed declines around the Elizabeth Bay beach. Damara Tern breeding pairs decreased two- to three-fold since the mid-1970s, and shorebird density along the beach showed a large four-fold decline from 220 to 41 birds/km of beach. By contrast, controls from other Namibian beaches indicate little change in shorebird density. Grosse Bucht, the closest south-facing sandy beach, showed stable to increasing numbers of shorebirds over the period 1992–2004. This trend is reflected in other Namibian beaches, including the richest shoreline (30km beach, Walvis Bay–Swakopmund: Simmons *et al.* 2001), where shorebird numbers have remained stable over a 30-year period. In 1977, a density of 448 birds/km was recorded in December–January (Whitelaw *et al.* 1978), while 20 and 21 years later (1997–1998), 511 birds/km and 451 birds/km were recorded respectively (R Braby in Jarvis *et al.* 2001). This long-term stability is found in shorebird counts at major coastal wetlands such as Walvis Bay and Sandwich Harbour, which have shown stable or increasing numbers of shorebirds in the last few years (e.g. Simmons 1999, Wearne and Underhill 2005)).

Numbers of Damara Terns have also shown stable trends over extended periods on the central Namibian coast where they have been monitored for 15 years (Simmons *et al.* 1998, Braby *et al.* 2002). Therefore, the steady decline in numbers of terns at Elizabeth Bay also appears to be a phenomenon peculiar to the bay. While such a decline is insignificant in terms of the world population of about 6 500 pairs (Simmons *et al.* 1998), it is significant for the Sperrgebiet. At 20 pairs, the colony at Elizabeth Bay was the largest in the proposed Sperrgebiet National Park. A CSIR (2002) report predicts that marine-associated biota around Elizabeth Bay will not recover for several decades, thus reduced populations of terns will probably persist through the first few decades of the Park's existence. Furthermore, a 20-fold increase in volume of fine sediment is due to be released in future years (CSIR 2002). Thus, it is likely that tern numbers will decrease further.

African Black Oystercatcher numbers were more stable at Elizabeth Bay, which itself is unexpected given the increasing numbers of African Black Oystercatchers in both central Namibia (Leseberg 2001) and southern Namibia (Simmons *et al.* MS). Namibian population numbers appear to have increased about 50% in the last 12 yrs (Simmons *et al.* MS) and Elizabeth Bay remains the only area not showing an increase in birds. While few are breeding birds, this area is the core of their distribution in Namibia (Martin 1997) and it is a recently discovered nursery area for sub-adult birds from South Africa (Leseberg 2001, Hockey *et al.* 2003).

Reasons for reduced shorebird numbers

It would be simple to attribute the decline in Damara Terns to habitat alteration of tern breeding sites through the diamond-mining process. However, no areas where the terns nest or once nested (Johnson 1979) on the gravel plains have been mined at any stage during the study period (RE Simmons pers. obs.). A second possibility is that poor food resources have influenced population numbers; among other species of tern, poor food resources are known to reduce the number of breeding pairs and reduce breeding success (e.g. Nisbet 1978, Monaghan *et al.* 1989). Foraging observations of the Elizabeth Bay terns indicated that, not only were birds avoiding the outlet pipe and the sediment plume around it, but the foraging success of adults watched during plunge-diving into the bay was lower than previously recorded from either the Cunene River Mouth, Namibia (0.22 fish/min of foraging: Simmons and Braine 1994) or Port Nolloth, South Africa (0.48 fish/min: J Cooper unpubl. data pers. comm.). Because other tern colonies have not declined in the same period (Simmons *et al.* 1998, Braby *et al.* 2002), the decline is also peculiar to Elizabeth Bay. The long-term nature of the decline also suggests that it is not due to annual fluctuations resulting from *El Niño* pertubations, for example.

Studies of the biomass of surf-zone fish — those targetted by foraging Damara Terns (Simmons and Braine 1994) — indicated that numbers were very low in exposed and sheltered sites at Elizabeth Bay, compared with Grosse Bucht (control site) and the Lüderitz Lagoon (Clark *et al.* 1998). For example, the maximum biomass from any of the 12 sites sampled at Elizabeth Bay (15kg) was about threefold lower than the maximum biomass found at two sites in Grosse Bucht (45kg). Abundance of fish was also significantly lower per haul (84 fish) at Elizabeth Bay than at Grosse Bucht (186 fish) (Clark *et al.* 1998). This suggests that fish abundance alone could account for the low dive success recorded for the Damara Terns. However, fish availability may also play a role in the turbid waters, because visibility is decreased to 5cm below the surface, and Clark *et al.* (1998) found that fish abundance was almost three times greater within the plume (121 fish/haul) than outside it (46 fish/haul). These are the areas where fish would find refuge from aerial predators such as plunge-diving terns, and this would explain why terns never dived into these waters and moved away from the plume. The low abundance and low availability of surf-zone fish in Elizabeth Bay can, therefore, explain the low foraging success of the terns and could explain the low breeding numbers of terns, compared with the pre-mining period. The foraging success of terns at Grosse Bucht has not been studied, but it is known that, along with the higher fish abundance at this site (Clark *et al.* 1998), more Damara Terns breed there (11–15 pairs: Simmons and Brown 2005), despite the bay being smaller.

Is the fine sediment slurry, introduced into the bay since 1991 from the diamond mining, also at the heart of the reductions of shorebirds and the stable numbers of oystercatchers? Earlier assessments (Pallet 1995, CSIR 2002) concluded that the fine sediment introduced into the bay, which circulates and accretes on the beach, may smother habitat for fish, seaweed and limpets, to varying degrees (Parkins and Branch 1997). This was evidenced by a decline in abundance of three species of grazing *Patella* limpets between control sites and impacted sites in Elizabeth Bay (Bustamante *et al.* 1993, Pulfrich *et al.* 2002a), and the elimination of myriapod and arachnid species on sandy shores exposed to diamond mining south of Luderitz (Griffin 1993). White Mussel *Donax serra*, a food source of African Black Oystercatchers in Namibia (Leseberg 2001), has also been eliminated from the central part of the beach (McLachlan *et al.* 1994). The 1.5 million cubic metres of sediment introduced per annum into the bay (Roux 2003) added 200m of sand to the beach in three years, gave the beach front a much steeper profile, reduced the size of the surf zone, and introduced coarser-grained sand to the beach (Pallett 1995, Clark *et al.* 1998). These changes and the sediment plume circulating in the bay, which is visible from aerial photographs (Pallett 1995, Tarr 2003), suggest that the habitat for fish and molluscs has been compromised. This can explain why the most affected birds were the shellfish-eating species such as turnstones and oystercatchers, rather than those feeding on invertebrate fauna, such as Sanderlings.

These results are at odds with the impacts predicted by the CSIR (2002, Table 4.4), in which they expected ‘minor severity’ of the smothering on ‘beach macrofauna available as a food source to coastal seabirds and surf-zone fish’. They predicted instead that the sediment would be blown inland by the strong southerly winds in this region (CSIR 2002). Reasons for the inaccuracy of the CSIR predictions probably relate to wave action within sheltered sites being insufficient to disperse deposited fine sediments. While the impact has proven significant on most shorebirds assessed, the extent of the impacts may not spread far outside the bay, as evidenced by the lack of decline on the Grosse Bucht beach, 19km to the north.

Other impacts of diamond mining on avifauna

Is there additional evidence that diamond mining has negatively influenced bird populations? Throughout this region, Simmons and Cordes (MS) compared shorebirds and Damara Terns from similar habitats inside, and immediately outside, the main diamond-mining area. Data from Elizabeth Bay are included in Table 1. Other comparisons from 1996 indicate that shorebird species richness was lower in Diamond Mining Area 1 (hereafter referred to as ‘inside’) than outside the Diamond Mining Area (hereafter referred to as the ‘outside’) (16 species *vs* 21 species) in similar lengths of sampled shoreline (36.7 and 30.8km). Shorebird densities were threefold lower (14 birds/km) inside than immediately outside (39 birds/km), despite similar proportions of sandy and rocky habitats. When assessed strictly by habitat type ‘inside’ and ‘outside’ the mined areas, sandy beaches were similar in bird numbers. However, kelp-strewn sandy beaches ‘inside’ supported 18 birds/km while those ‘outside’ supported nine-fold more birds (167 birds/km). Rocky shores showed the same trend with 14 birds/km ‘inside’ and 107 birds/km ‘outside’ (Simmons and Cordes MS). That some invertebrates have been lost from these beaches (Griffin 1993) is consistent with the reduction in abundance of shorebirds utilising them.

Conservation measures

Given the magnitude of the avian declines and the possibility that this is directly or indirectly due to sediment circulating in the bay and settling on the beach, are there conservation measures acceptable to both Namdeb and to the future national park status of the Sperrgebiet? One possibility is to deposit the sediment slurry directly onto the large salt pan immediately behind the beach environment. Because the sediment pipe crosses this pan, it involves no increased lengthening of the outlet pipe. The sediment is likely to quickly dry and, as predicted by the CSIR (2002), will be blown northward by the strong southerly wind, away from the bay and the most active diamond-mining area. There are no breeding birds nor rare plants in this wind corridor and all Damara Terns nest on the raised gravel plains east of here (RE Simmons pers. obs.). The original decision to place the fines into the sea was made because it was thought the sediment would be carried away by currents and winds, and because of the possibility that diamondiferous ore bodies may be present under the salt pan (R Spaggiari pers.comm). Deposition of the sediment on the salt pan for a 6–12-month trial period would allow an assessment of the rate of recovery for smothered shellfish populations in the bay and the avifauna along the beach. The vegetated *Salsola* hummocks — that once formed the boundary of the old beach and are now about 500m from the current beach front — will remain unaffected because the sediment will be deposited behind them. If this halts the decline of the shorebird, and particularly the globally near-threatened Damara Tern or oystercatcher populations, then the mining company can initiate long-term plans to deposit sediments on the pan. The plan will allow an unparalleled before-and-after assessment of the effects of sedimentation on the biological diversity of the area and allow future conservation planning for other mining sites in southern Africa and elsewhere.

In summary, several lines of evidence suggest that Damara Tern have declined in numbers since the Elizabeth Bay diamond mine began operation. This is supported by steady declines in shorebird densities over the last 25 years, relative to control sites. Sedimentation and smothering of marine biota in the bay is suggested as the reason because of the low foraging success of the Damara Tern, their avoidance of the outlet pipe, and the low abundance and availability of surf zone fish in this bay. Steady declines in species eating shellfish strongly suggest that limpets and other invertebrates have declined or become less available. I suggest that the fine sediments should be deposited on the salt pan and not in the bay for 6–12 months and the effects closely monitored in a bay-watch programme. All results should be evaluated shortly after this. This will allow a direct test of the hypothesis that sediments are detrimental to bay fauna and flora (and algae) and will allow fish, shellfish, kelp and bird populations to begin to recover to pre-mining populations. If results are promising, a long-term plan to deposit the fines on the salt pan should be made.

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