THE BIOLOGY AND MANAGEMENT OF THE REGIONALLY THREATENED DAMARA TERN (*Sterna balaenarum*) AT STRUISBAAI, SOUTH AFRICA

BY

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ABSTRACT

The breeding success of the damara tern Sterna balaenarum, *between Struisbaai and Arniston, on the South African south coast, was monitored on a daily basis during the five month breeding period (October 1995-February 1996). The breeding population was estimated at between 18-22 birds, which is approximately the same as was estimated 16 years ago. Breeding took place six kilometres west of the De Mond Nature Reserve. No breeding took place at the previously reported sites within or east of the De Mond Nature Reserve. Breeding success was extremely low (15.3 %), with only three chicks fledging from a total of 17 nests. It was recorded, for the first time, that pairs could lay up to two replacement clutches after earlier clutch failure. Breeding failure was caused by rain, sand inundation of eggs, eggs and chicks being crushed by vehicles, disappearance of chicks, possible disturbance by the observer and an unknown cause. Birds were seen foraging in the Heuningnes Estuary, within the surf zone along the coast and out at sea. Foraging for the provisioning of chicks appeared to occur predominantly in the surf zone and further out to sea. Observation of the hourly provisioning rates showed a daily increase in the quantity of fish being eaten by the chick until the chick was eight days old, after which it remained fairly constant. No chick mortality could be attributed to starvation. If the damara tern population is to persist in the area, it is recommended that the inter-dune slacks and dune system be closed to vehicles and pedestrians, that beach users be educated by means of signboards and television programmes (eg. 50/50), that marram grass* Ammophilia arenaria *be removed from the frontal dune systems and inter-dune slacks, and that further research be conducted on the Struisbaai damara tern population.*

Keywords: Damara tern, breeding success, disturbance, foraging, provisioning, management, Struisbaai.

INTRODUCTION

The damara tern *Sterna balaenarum* is listed as rare, both in Africa and South Africa, due to its small population size and the wide range of threats to its survival (Brooke, 1984; Collar & Stuart, 1985). The tern is endemic to the coast of western and south-western Africa (Collar & Stuart, 1985). The total world population has been estimated at 13 000 birds, the majority of which breed in Namibia (Simmons, 1993). The total population in South Africa, where the tern is a breeding austral summer visitor, has been estimated at less than 120 pairs (Brooke, 1984). Breeding may also take place in Angola (Brooke, 1981). Breeding occurs in small, loose colonies in gravel flats, pans and among slacks within dunefields (Collar & Stuart, 1985).

In the past 20 years breeding in South Africa has occurred in two main areas: at pans between the Orange River Mouth and Kleinsee on the North Cape Coast, and at scattered sites along the South Coast, from Brandfontein Private Nature Reserve to the Sundays River Mouth (Algoa Bay) (Burger *et al.*, 1980; Randall & McLachlan, 1982)(Fig. 1). In the Western Cape breeding is presently restricted to the Brandfontein Private Nature Reserve and to the coast between Struisbaai and Arniston including the De Mond Nature Reserve (J. Cooper pers. comm.). Management of these colonies is important to ensure the persistence of the damara tern in this, its most southerly distribution.

The regional conservation authority, namely the Western Cape Department of Nature Conservation, is concerned that human disturbances along the coast between Struisbaai and Arniston result in reduced breeding success. A better understanding of the local breeding biology of this species is needed to allow for management of their populations. This paper reports the on the breeding biology of the damara tern population between Struisbaai and Arniston, and includes information on breeding success and provisioning of chicks. It identifies factors contributing to breeding failure, and proposes management options to ensure that this population is maintained.

MATERIALS AND METHODS

Study area

The study was conducted along the coast between Struisbaai and Arniston (Fig. 2). The Struisbaai dune system is 23 km long and 0.7 km wide and is characterised by low frontal dunes with pebble inter-dune slacks. The back dunes are partially vegetated and have vegetated inter-dune slacks. The dune system, 1.7 km to the east and 2.8 km to the west of the Heuningnes River mouth, has been artificially stabilised to prevent the closure of the mouth due to drift sand. This has been done using brushwood and poles and by planting alien marram grass *Ammophilia arenaria*, and indigenous *Chironia bacciffera*, *Myrica cordifolia*, *Metalasia muricata* and *Chrysanthemoides monilifera*, making it unsuitable as a breeding habitat for damara terns.

The coast between Struisbaai and Arniston is largely undeveloped with limited vehicular access points (Fig. 2). The stretch of coast northeast of the Heuningnes Estuary is practically free of human disturbance. Vehicular activity is limited to official vehicles, while pedestrian activity is limited by the distance to the few vehicle access points. The southwestern stretch of the coast is open to pedestrians but vehicular access is restricted to a single access point at Die Plaat and is controlled by a permit system. During 1995, 3 200 permits were sold (M. Carstens pers. comm.). Recreational anglers are the most regular users of both stretches of the coast.

Counts and nest location

The beach between Struisbaai and the Heuningnes Estuary (from here on referred to as the Struisbaai beach) was surveyed daily (by motorbike), from the beginning of November 1995 to the end of February 1996. The area was surveyed for nests, and the number of juvenile (still with some brown feathers < 1 yr old), immature (no black cap < 2 yrs old) and adult (black cap visible > 2 yrs old) damara terns was counted (Collar & Stuart, 1985). The coastline east of the Heuningnes Estuary, including Die Mas, was surveyed monthly for signs of breeding activity. Beach counts represent the maximum number of damara terns seen on any single occasion during the week. Weekly counts of damara terns roosting on the estuary were conducted at low tide.

Behavioural observations

During October, observations of courtship behaviour were made in the Heuningnes Estuary. From the beginning of November to the end of February courtship behaviour, nest-site selection, brooding, provisioning, and chick behaviour were monitored at the nest sites. To determine hourly provisioning rates individual chicks were watched from 8 am until 4 pm, up to the age of 13 days old, after which it became increasingly more difficult to follow chicks and obtain accurate data. During this time the length and number of fish given to a chick were recorded. Fish length was assigned to one of three size categories: 20-40, 40-60, 60-80 mm, estimated relative to adult tern's bill length (30 mm) and head length (80 mm). To account for differences in fish size, fish equivalents were calculated assuming that the mass of a fish was proportional to the length cubed (Bennett, B.A. unpublished data). The hourly provisioning rate was calculated using periods of at least two hours during which all feeds were accurately recorded. Foraging dive success rates were monitored, throughout the breeding season, for individual terns in different foraging habitats and varying weather conditions. All observations were made using a Kowa telescope (20 x magnification) and a pair of binoculars (8 x 30 magnification).

Nest monitoring.

Nests were monitored on a daily basis and the laying date, clutch size, and date of hatching were recorded. Obvious features such as kelp *Ecklonia maxima*, planks, vegetation and beach litter occurring within a two meter radius of the nest were noted, and the distances between nearest active nests (nearest neighbour distance) were measured. The average incubation period was calculated from nests that had recorded dates of laying and hatching. Chicks were considered to have fledged when they were first seen flying. The inter-brood period was recorded as the time between losing a chick or egg and the laying of another egg.

Breeding success

Breeding success was divided into three stages: (1) survival through incubation; (2) survival through hatching; (3) survival through to fledging (Mayfield, 1975). Breeding success was calculated using Mayfield's (1975) methods. No nests were excluded from the sample, as either the date of laying or the date of hatching was known for all eggs and the average incubation period was used to estimate the date of laying for eggs with unknown laying dates. The cause of egg or chick loss was inferred from vehicle and animal tracks, weather conditions, including wind-induced sand movements, and disturbances caused by the observer.

Measuring and ringing

Eight adult damara terns were caught using a walk-in trap (Simmons & Braine 1994). The terns were sexed by bill length after Simmons & Braine (1994), using vernier callipers to measure the exposed culmen to the nearest 0.1 mm. Adults were ringed with a metal ring on the right leg and a double colour combination on the left leg. Three chicks were ringed in a similar manner but were given a cohort colour of a single yellow ring on the left leg. Cohort colour bands have been placed on chicks from the Struisbaai area for the past two years (B. Dyer, South African Sea Fisheries Research Institute pers. comm.).

Disturbance

At the tern breeding area pedestrian, dog and other possible disturbances were recorded from actual sightings or from the evidence of tracks in the area.

Sets of ten sand-coloured plasticine "eggs" were placed in a predetermined pattern in a 10 m^2 area (Fig. 3) at three different test sites: test site 1 at the 1995/96 main breeding area; test site 2 at the vehicle entrance to the Struisbaai beach; and test site 3 in the De Mond Nature Reserve (Fig. 4). Test sites 1 and 2 had active nests during the 1995/96 breeding season while test site 3 was known to be active during the 1994/95 breeding season. The plasticine "eggs" were checked daily to see whether any had been crushed by vehicular or pedestrian traffic, or disturbed in any other way.

Public awareness

Interviews were carried out at the breeding area over the December holiday period to determine drivers' awareness of the regulations pertaining to areas where off-road vehicles may be driven, the need for a beach permit, and the importance of dune slacks as a breeding area for damara terns and other shore nesting birds.

RESULTS

Counts

Beach counts conducted between 1 October 1995 and 12 March 1996 showed an increase in numbers of adult damara terns through the breeding season (Fig. 5A). There was a sudden increase at the end of January-beginning of February, possibly due to the arrival of migrating birds that had bred further east. The numbers decreased again at the end of February. The number of juveniles increased at the end of January and decreased towards the end of February. One immature bird was seen during December. The number of adult damara terns on the estuary was slightly higher during October compared to the other months, with a further decline occurring at the end of February (Fig. 5B). On one occasion only was a juvenile damara tern seen on the estuary. This juvenile which was being fed by an adult, was not ringed, and thus neither bird was from the Struisbaai breeding population.

The Struisbaai breeding population was estimated to be between 18 and 22 birds. This estimate was based on the ringing of adults which allowed for the identification of replaced clutches, on the assumption that pairs stayed together after losing a clutch, and on the number of nests.

Courtship

Courtship behaviour was observed on the estuary and on the beach in front of the breeding area, from the beginning of October until the end of the first week of February. The establishment of a courtship pair was initiated by a male presenting and feeding fish to a female, and included behaviour typical little tern *Sterna albifrons*, such as high speed chases, towering dominance flights, and much calling between birds (Haddon & Knight, 1983). No fish were presented or given during copulation, as has been seen in the little tern (Haddon & Knight, 1983). In two cases, where both adults of a pair were individually marked, it was observed that the pairs stayed together after losing a brood. Courtship was again initiated by courtship feeding.

Breeding area

Breeding took place approximately six kilometres west from the area previously reported in the De Mond Nature Reserve (Burger *et al.*, 1980; A.J. Williams CNC, pers. comm. for 1994/95 breeding season). No damara tern nests were found within the De Mond Nature Reserve or northeast of the Heuningnes Estuary during the 1995/96 breeding season.

Three breeding areas were identified (Fig. 4). The first was situated approximately 300 m northeast of the vehicle access point to the Struisbaai beach, in dune slacks immediately above the Spring High Water Mark (SHWM). This area consisted of 14 nests (maximum of 10 breeding pairs) and was active throughout the breeding season. The second breeding area (*ca.* 500 m from area 1) was situated immediately above the SHWM on a large dune slack approximately 250 m long and 50 m wide, adjacent to the southwest side of the vehicle access point. In this area breeding was attempted only once, during November. The third breeding area was situated on a gravel outcrop approximately 250 m inland from the first breeding area. This area was active during December and January and consisted of two nests from breeding pairs that had failed previously at areas 1 and 2.

Breeding areas 1 and 3 were characterised by sparse vegetation cover of marram grass and *Myrica cordifolia* respectively, whereas area 2 was virtually free of vegetation. Both areas 1 and 2 were characterised by a mixture of small pebbles (ranging from approximately 5 cm to 30 cm in length) and broken shells (predominantly white mussel *Donax serra*), whereas area 3 had a mixture of sand and gravel.

On a finer scale, nine of the 17 nests were situated within 2 m of distinctive features such as beach litter (n = 3), kelp (n = 1), beach litter and kelp (n = 1), planks (n = 2) or small shrubs (n = 2), while the eight remaining nests were not situated near any distinctive features. Analysis of nearest neighbour distances showed that nests were on average 73 m apart (SD 45 m; range 30-170 m; n = 10 excluding the single nest at area 2). Nests were situated on average 59.4 m (S.D 89.7, range 1-290 m) from the SHWM, while six of the nests were situated less than 10 m away from the SHWM.

Nest sites

Prospecting for suitable nest sites took place approximately three days before egg-laying. Both sexes participated in finding a suitable position and a number of nest-scrapes were made before the egg was laid. The terns placed a few shells and small stones around the rim of the nest-scrapes.

Egg-laying

Clutch size was invariably one for all clutches laid (n = 17). The first egg was laid on 11 October. Egg-laying peaked in November and December, with only two clutches being laid in January (1 January and 7 January) (Fig. 6). Both clutches laid in January and at least three and possibly five (including two from unmarked pairs of birds) of the eight clutches laid in December, were repeat attempts after earlier clutches had failed. This suggests that the peak for first clutches was in November, while the majority of clutches laid in December were from renesting birds (Fig. 6). The average period between losing a egg or chick and relaying was 10.9 ± 3 days (range 7-16 days, n = 8). Two pairs replaced clutches twice, while another two, or possibly four pairs, were recorded relaying once, after losing their initial clutch (Fig. 6).

Incubation and hatching

The average incubation period was 23.8 ± 1.0 days (range 23-25 days) (n = 6), approximately five days longer than the period recorded in Namibia (Simmons & Braine, 1994). Both parents incubated the egg. Egg hatching peaked in November and January, with the peak in January resulting from the repeat clutches laid in December (Fig. 6). Eggs were starred approximately a day before hatching. After the chick had hatched the eggshells were removed by the parents and dropped at least 100 m from the nest.

Brooding

Newly hatched chicks were brooded for the first three days, and an adult remained in attendance until the chick was approximately ten days old. Chicks more than three days old were brooded only in poor weather conditions (strong winds or rain). Parents remained with chicks older than 10 days if the chicks had been disturbed recently or were trying to fly. Brooding and attendance duties were shared by both parents.

Provisioning

Chicks were fed by both parents, starting shortly after the chick had hatched and continuing for two and a half months after fledging (Clinning, 1978). One chick hatched at 15h30 and was fed a 30 mm fish 24 minutes later. The maximum length of fish fed to chicks gradually increased with the chick's age: chicks less than three days old were given fish of up to 40 mm in length, chicks less than four days old received fish up to 60 mm in length, while those of six days old received fish up to 80 mm in length (Fig. 7A)(51 hours observation). Only chicks older than 18 days were fed fish longer than 80 mm and no chicks were seen receiving fish smaller than 20 mm long. The provisioning rate increased for each size-class of fish fed but decreased when the next size-class was introduced (Fig. 7A). Hourly provisioning rates showed a daily increase in the quantity of fish (fish equivalents) being eaten by the chick until the chick was ten days old, after which it remained constant (Fig. 7B). Fish regurgitated during the ringing procedures of chicks and adults indicated that estuarine round herring *Gichristella aestaurta* (n = 3), harder *Liza richardsonii* (n = 1), cape silverside *Atherina breviceps* (n = 1) and Clinidae (n = 1) were taken as food. None of these has been recorded previously as food items of the damara tern (Clinning, 1978; Simmons & Braine, 1994).

Provisioning adults appeared to come in from the sea, particularly from the sheltered western end of Struisbaai. Returning parents called to their chick, which flapped its wings and called in response to its parents, indicating individual vocal recognition. The parent usually made a number of landings away from the chick before approaching it with the fish. If potential predators, such as kelp gulls or black harriers *Circus maurus* were present, they were mobbed until they left and only then was the chick fed. Some chicks, apparently satiated, refused fish which the parents then ate. All fledged chicks were still receiving fish from their parents at the end of February. No chick mortality could be attributed to starvation.

Foraging

Damara terns were observed feeding in the Heuningnes Estuary, within the surf zone along the coast, and out at sea. Most foraging was done in the surf zone and further out at sea.

Foraging damara terns in the estuary had a dive success rate of 28.6 % (n = 21). These terns were feeding in shallow clear water with a moderate northwesterly wind on an incoming tide. Monitoring of dive success rate in the surf zone and sea was not possible because the terns covered large distances between successive dives, thus making it impossible to see if a dive was successful. On one occasion a record provisioning rate was observed when a mother fed a 14 day old chick 13 fish, 25 to 30 mm long, in 20 minutes. This was an average of one fish every 1.5 minutes. The fish were caught within the surf zone near the nesting area on a clear day in a moderate to strong southeasterly wind. Dive success was 100 % (n = 5) during this time.

Fledging

Only at the end of the breeding season were three chicks fledged successfully, the first chick on 31 January and the last on 25 February (Fig. 6). Chicks were seen flying for the first time at an age of 24 days (n = 3), while two chicks older than 24 days, died before flying. One of these chicks had deformed wings and feet and thus could not walk properly or fly, although it was past the age at which other chicks fledged. This chick eventually died in cold rainy weather (26 days old). Chicks, once able to fly, moved onto the beach in front of the nesting area.

Breeding success

Of the 17 eggs laid during the breeding season 11 hatched and three chicks fledged successfully. Egg and chick mortality peaked in December (six eggs and three chicks lost), with three eggs and three chicks being lost in the last week of December (Fig. 6). Three eggs were covered by wind-blown sand (21.4 %) and two chicks died in cold, torrential rain (14.3 %), four chicks disappeared (28.5 %), two eggs (14.3 %) and one chick (7.1 %) were crushed by off-road vehicles, while one egg (7.1 %) was deserted, apparently after the observer had unintentionally disturbed a laying bird, and one three day-old chick was found dead from an unknown cause (7.1 %) (Table 1 & Fig. 6).

The probability of surviving through the incubation period was 56.2 % (251 days observation), through hatching was 100 % (n = 11) and through to fledging was 27.3 % (crude estimate)(Table 2). Mayfield's (1975) method was not used to calculate fledging success as chick mortality was not evenly distributed throughout the nestling period. Mortality was higher for very young chicks (age 1-4 days) and for chicks about to fledge (age 21-26 days). The probability of surviving the total nesting period was thus only 15.3 %.

Disturbance

Incubating birds responded differently according to the type of disturbance. Possible predators (avian and terrestrial, including people) were mobbed by incubating birds and adult terns with chicks until the predator left the area. Vehicles approaching closer than about 10 m caused incubating terns to fly off the nest, and to return once the vehicle had left the area. The intensity of mobbing and/or the speed at which the incubating bird returned to its nest increased just before the egg began to hatch. Chicks younger than 10 days generally lay flat and remained motionless if disturbed or if warned by parents of a threat, whereas older chicks sought cover behind vegetation or larger rocks or moved away from the approaching threat.

During the five month study period pedestrians were recorded entering the nesting area on five occasions and dogs on two occasions. On two occasions mongoose tracks were seen within two metres of a nest-scrape with a newly hatched chick. However no egg or chick losses could be attributed to pedestrians, dogs or mongooses.

Kelp gulls caused a continuous disturbance to the damara terns by flying over the terns' breeding area on the flight path to and from their own nesting area. Kelp gulls were also attracted to the breeding area when temporary pools formed (where they bathed or fed on small trapped fish) or when they were fed by nearby fishermen.

The proportion of plasticine "eggs" crushed by vehicles at the three different test sites showed a significant difference in the level of disturbance between sites 1, 2 and 3 (X_2 test $P < 0.001$) (Table 3). Test site 2 showed greater levels of disturbance at the beginning of December compared to the other two sites at this time. Levels of disturbance increased dramatically for both test sites 1 and 2 during the last two weeks of December, when site 1 showed far greater levels of disturbance than site 2. The loss of the two eggs and one chick in breeding area 1 correlated with the increase in levels of disturbance at test site 1 at the beginning of December (Fig. 8). The probability of a plasticine "egg" being crushed in 23.8 days at test site 1 was 0.97 %. Thus, using the probability theory, it was calculated that the probability of two or more of the 17 real eggs being crushed was less than 1.16 %. However, 11.8 % of the real eggs were crushed by vehicles indicating that the probability of hitting real eggs was higher than that predicted from the plasticine "egg" experiment. Vehicle disturbance was not, however, evenly spread over test site 1, the three "eggs" within 10 m from the SHWM were crushed 28 times, while of the remaining seven "eggs", further than 10 m from the SHWM, only two were crushed. Two of the six real eggs less than 10 m from the SHWM were crushed. At test sites 1 and 2 disturbance levels decreased during the first two weeks of January and remained low for the remainder of the breeding season (Fig. 8). No "eggs" were crushed at test site 3 although occasional vehicle tracks were seen in that vicinity.

Public awareness

Twenty off-road vehicle drivers traversing the breeding area were interviewed, 13 of whom were fishermen and seven were sightseers. Only eight of the drivers had permits to be on the beach. Two of the drivers knew that they were not allowed to drive above the high water mark and both were in the area because temporary pools, caused by spring tides, prevented access to the area below the high water mark. None of the drivers interviewed knew that shore birds nested on pebble slacks so close to the sea, or knew of the existence of the damara tern. Eighteen of the drivers thought that the erection of more informative signboards would be effective in reducing vehicular disturbance of the terns.

DISCUSSION

Population trends

The damara tern population in Namibia appears to be large (*ca.* 13 000 birds) and relatively stable (Simmons, 1993), while the South African population appears to be declining and is in need of protection. A survey conducted during the 1995/96 breeding season found that only two of the seven areas active in the Western Cape during the 1970s and 1980s were still active (J. Cooper pers. comm.). Two of the areas lost in the Western Cape (De Mond and Die Mas) were from breeding areas between Struisbaai and Arniston. Unless the Struisbaai colony receives adequate protection and management it too may disappear. The Eastern Cape colony in the Alexandria Dune Fields appears to have remained stable (Watson & Kerley, 1995), while in the Northern Cape a new colony was found, increasing the number of colonies between the Orange River and Kleinsee to five (J. Cooper pers. comm.).

In September 1978 the damara tern population at the De Mond Nature Reserve was estimated from a single count at 36 adult birds (Burger *et al.*, 1980), although that early in the season it could have been a migrating flock en route to the Eastern Cape. During the 1979/80 breeding season the population was estimated at 22 birds, 17 of which were in breeding plumage (Burger *et al.*, 1980), indicating that the population at De Mond has changed very little over the past 16 years. These figures, however, may be under-estimates as they are based on short observation periods or one-off counts.

Breeding period

Damara terns begin to arrive at De Mond in September and remain until March, possibly April, but no terns have been seen during the winter months of May and June (Burger *et al.*, 1980). The breeding period at Struisbaai spanned four months (October to January) during which eggs were laid, a much shorter period than the eight months (November-June) reported for the damara terns in the Skeleton Coast Park, Namibia (Simmons & Braine, 1994). Egg-laying peaked in December at Struisbaai and the West Coast Recreational Area (P. Tarr in Simmons & Braine, 1994) but further north, in the Skeleton Coast Park, the peak was in January (Simmons & Braine, 1994). Due to the short breeding period along the South coast, and the fact that fledglings are dependent on their parents for at least two and a half months after fledging (Clinning, 1978), it is unlikely that damara terns would re-breed along the South coast once they have raised a chick successfully (Randall & Mclachlan, 1982).

Breeding areas

Alternation of breeding areas between seasons has been recorded before in damara terns, at Elizabeth Bay in Namibia (Johnson, 1979) and at De Mond (Burger *et al.*, 1980; Crawford *et al.*, 1994). Desertion of breeding areas may be due to human disturbance, heavy predation on eggs and chicks, physical alteration of the breeding area, and/or the limited availability of food within the foraging area (Crawford *et al.*, 1994).

The kelp gull colony on the southwestern side of the estuary has increased from one nest in the early 1980s (Cooper, 1984; Underhill & Cooper, 1984) to the production of over 400 chicks in 1995/96 (pers. obs.). This increase near the previously recorded damara tern breeding area at De Mond, and the fact that the dune slacks had not been blown clean of sand, may have caused the move to the present breeding location. There may, however, be a natural cycle, with the annual location of breeding sites depending on the availability of suitable breeding areas and proximity to foraging areas. The change in breeding areas from areas 1 and 2 to area 3 during the course of the 1995/96 breeding season appeared to be a result of increased vehicle disturbance and previous clutch failure at areas 1 and 2. This highlights one of the problems in conserving the damara tern, namely that an area set aside as a reserve may be deserted unless disturbance is kept to a minimum (Frost & Shaughnessy, 1976).

Reports of distances between nearest active nests have ranged from as little as 20 m (De Villiers & Simmons, in Simmons & Braine, 1994, Hottentots Bay, Luderitz) to 100-200 m (Frost & Shaughnessy, 1976, Swakopmund; Randall & Mclachlan, 1982, Sundays river; Watson *et al.*, 1996, Alexandria Dune Field; Simmons & Braine, 1994, Skeleton Coast Park). Close nest spacing may be linked to predator-free environments (Simmons & Braine, 1994), but may also be associated with limited suitable breeding habitat. The fact that three nests were lost as a result of sand inundation, in two cases only a couple of days after egg-laying, would appear to support this latter hypothesis. It is possible, however, that these nests belonged to inexperienced birds laying for the first time.

The location of the majority of nests near to obvious features has been reported before, for damara terns (Simmons & Braine, 1994; Watson *et al.*, 1996) and for other tern species (Saino & Fasola, 1993). These objects seem to be important in allowing adults to locate their cryptic eggs and thus movement or removal of objects around the nest should be prevented or kept to a minimum.

The average distance of nests from the sea at Struisbaai was far less than the 3.18 km in the Skeleton Coast Park (Simmons & Braine 1994) and the 1.9 km of the West Coast Recreation Area, Namibia (P. Tarr in Simmons & Braine, 1994), but was similar to previous South African reports in which nests have been within 200 m of the sea (Burger *et al.*, 1980; Randall & Mclachlan 1982; Watson *et al.*, in press). On the south coast of South Africa suitable breeding habitat is restricted to the immediate coastline (J. Cooper pers. comm.), whereas in Namibia breeding occurs up to 8 km from the coast (Simmons & Braine, 1994). The narrow strip of breeding habitat in South Africa results in conflict between people and damara terns and thus strict preventative management is needed to reduce this conflict.

Foraging and provisioning of chicks

Burger *et al.* (1980) stated that damara terns foraged mainly within the Heuningnes Estuary and that fledglings were fed on the estuary, while provisioning adults were seen flying from the estuary to the nesting site. This was not the case during the 1995/96 breeding season. Despite the fact that the current breeding area was now 11 km from the Heuningnes Estuary, chicks appeared to be well fed and no chick loss could be attributed to starvation. During this study, terns (adults and fledged chicks) were seen foraging mainly in the surf zone and further out at sea. Braby *et al.* (1992) have also recorded terns foraging along a high energy shore on the Namibian coast. The importance of estuaries and sheltered bays for foraging may well have been over-emphasised in the past (Frost & Shaughnessy, 1976; Clinning, 1978; Johnson & Frost, 1978; Burger *et al.*, 1980; Simmons & Braine, 1994) because foraging terns are more easily seen in these restricted habitats. Similar over-emphasis of estuarine habitats for foraging has occurred in the California least tern *Sterna albifrons browni* (Atwood & Minsky, 1983).

Adaptations of a single egg clutch

The damara tern is unusual in that normally one egg is laid (Frost & Shaughnessy, 1976). Single egg clutches in terns are generally associated either with pelagic foraging species, or with tropical species that forage close to their breeding area in waters that have a depauperate food supply (Frost & Shaughnessy, 1976). Single egg clutches are also associated with large eggs and long incubation periods (Lack, 1968). In the damara tern, selection for a single egg clutch reduces energy expenditure for each clutch, and allows for rapid replacement of a clutch and for the maximum growth rate of a chick through the fledgling period (Frost & Shaughnessy, 1976).

Breeding success

Breeding success at Struisbaai in 1995/96 was extremely low. During the 1979/80 breeding season at the De Mond Nature Reserve, breeding success was also very low, as only one chick from the six eggs laid reached flying age (Burger *et al.*, 1980). Despite the wide variety of predators in Namibia the percentage of monitored eggs that hatched there (72%) was slightly higher than at Struisbaai (65%) (Simmons & Braine, 1994). Massey and Atwood (1981) suggested that a fledgling/nesting pair ratio of 0-0.5 was poor, and that 0.5-1.0 was moderate for the California least tern, a species that has a clutch size of two. Using the fledgling/nesting pair ratio, the Struisbaai damara tern colony had a ratio of 0.3, and would thus be considered poor.

Causes of breeding failure

The loss of eggs and chicks to wind-blown sand and weather must be expected, but the relative proportion of losses caused by these stochastic events will vary from year to year. Loss of eggs to sand inundation has been recorded before (Johnson, 1979), although the frequency of occurrence has not been documented.

Unnecessary breeding failure was caused by vehicles whose drivers were ignorant and unwittingly drove over eggs or chicks, effectively reducing to half the possible number of chicks fledged. Although vehicles remained predominantly within 10 m of the SHWM, that was the area where a large proportion of the eggs were laid. Spring tides and storms aggravated conditions by creating large temporary pools between the neap high tide mark and the dune slacks, which included the vehicular entrance to the beach at Die Plaat. The temporary pools prevented fishermen and holiday makers from driving down to below the neap high water mark; instead they were forced to drive above the pools and thus through the damara tern breeding area. This in turn caused further problems as a distinct track developed approximately seven meters from the SHWM, that attracted motorists even after the temporary pools had disappeared. The sand dunes adjacent to the nesting area attracted off-road vehicle enthusiasts who drove through the nesting area in search of suitable terrain to test their driving skills. Such activities are illegal. Breeding failure due to vehicle disturbance may be reduced by introducing public awareness, and stricter control and management of the breeding area.

The disappearance of four chicks, two of which were at fledging age, could be attributed to predation or vehicle disturbance or a combination of both. The large number of kelp gulls that flew low over the damara tern breeding area, and the intense mobbing of the gulls by the terns, possibly indicates that the gulls are a threat to chicks. Chicks learning to fly are particularly vulnerable to predators such as kelp gulls, as they are more conspicuous at this stage. Vehicle and pedestrian disturbance may also have played a role in the disappearance of some of the chicks, as such disturbances caused chicks to move from cover thus making them more visible to predators. Similar observations have been made by Randall & Mclachlan (1982) at the Alexandria Dune Fields. The desertion of an egg shortly after egg-laying, because the observer disturbed the laying bird, highlights the problem that increased pedestrian and vehicle activity could have on the breeding success of the terns.

Although dogs were not a problem at the tern breeding area during the 1995/96 breeding season, dogs were seen entering the kelp gull colony (n = 5), and people were also seen hunting with dogs in the dune system (n = 2). The disturbance caused by dogs could increase in the future with increased use of the beach by the public. Loss of chicks to black-backed jackals *Canis mesomelas* and brown hyaenas *Hyaena brunnea* has been reported in Namibia (Simmons & Braine, 1994), and it could be expected that with the increased use of the beach, chicks would be lost to dogs.

Future problems

Physical alteration of the dune slacks is taking place, both at the previous years' breeding area and at the 1995/96 breeding area, as marram grass begins to grow into these slacks. The exact rate at which this is taking place was not possible to determine from this study. It is, however, known that damara terns will not breed in vegetated slacks (Burger *et al.*, 1980). If marram grass is allowed to continue its spread into the dune slacks the available breeding habitat may be lost in the future.

Future urban development adjacent to the nesting area would dramatically increase human related disturbance and may result ultimately in the desertion of Struisbaai as a breeding area.

Public awareness

The interviews showed a lack of public awareness of beach regulations and of the importance of the area for shore nesting birds, particularly the damara tern. Lack of awareness could be attributed to the inadequacy of the signboard at the entrance to the beach at Die Plaat. The signboard does not provide information on the beach regulations or identify ecologically sensitive areas. It is also out of the way of the direct flow of traffic and thus easily ignored. Although the Overberg Regional Service Council (ORSC) issued a pamphlet of beach regulations with each permit purchased, it did not appear to be effective as it was not read by the majority of drivers (M. Carstens ORSC pers. comm.). A more active and informative public awareness programme is needed to educate the public on beach regulations and the requirements of shore nesting birds.

MANAGEMENT

Management should not be species specific but needs to take into account other coastal breeding species (e.g. african black oystercatcher *Haematopus moquini*, caspian tern *Hydroprogne caspia*, whitebreasted cormorant *Phalacrocorax carbo* and whitefronted plover *Charadrius marginatus*) and the ecologically sensitive dune system.

The following measures are proposed for the effective conservation of the damara tern and dune system:

1) Signboards should be erected in obvious places at the entrance to the beach, and should inform beach users of:

    i) Beach regulations including a map of areas where access is prohibited e.g. the De Mond Nature Reserve and the dune system.

    ii) The importance of the area as a breeding habitat for the damara tern and other shore nesting species.

2) Poles or bollards should be erected along the eastern side of the access road to the Struisbaai beach as far as the spring high water mark, to prevent vehicle access to the sand dunes, the poles to be accompanied by signs identifying the area as an "ecologically sensitive area". The last pole at the SHWM should be accompanied by a sign identifying the spring high water mark.

3) The damara tern breeding area/s should be identified each year during October and November and demarcated using poles and signs along the border of the beach and dune slacks. As an alternative a number of poles and signs could be erected along the full length of the border, between the beach and the dune slacks, to demarcate that area as ecologically sensitive.

4) Education and law enforcement should be increased at the breeding area/s during the December holiday period and during spring high tide or storm conditions that create temporary pools.

5) Marram grass in dune slacks and along the small frontal dune systems around the slacks should be removed and monitored periodically to ensure that further encroachment into the slacks is prevented.

6) The damara tern population along the Struisbaai coast should be monitored to determine breeding success, population growth rate, and assess return of ringed birds.

7) The dune system and areas immediately north of the dune system need to be legally protected against any development that could threaten the damara tern and the dune system.

8) Dogs should not be allowed east of the vehicle access point to the Struisbaai beach.

9) Information boards should be erected at the Overberg Regional Service Council office and at the De Mond Nature Reserve office, highlighting the requirements of shore nesting birds and the problems caused by off-road vehicles on beaches.

10) The public needs to be informed of the requirements of shore nesting birds and the problems caused by off-road vehicles through a media campaign in the local press, appropriate magazines, and through television programmes such as 50/50.

11) A talk and slide show on the effects of off-road vehicles and the ecology of beaches and dunes could be given by Western Cape Department of Nature Conservation personnel to holiday makers at the Struisbaai Caravan Site.

12) Other important shore nesting species (e.g. caspian tern, african black oystercatcher and kelp gull) along the Struisbaai coast should be monitored to determine breeding success and population growth rate.

Management should be aimed at enlisting public support and cooperation in conserving the damara tern and its habitat at Struisbaai, and an ongoing monitoring programme should be implemented to ensure the effectiveness of this management.

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Table 1: Factors contributing to damara tern egg and chick mortality at Struisbaai during the 1995/96 breeding season.

Cause	Eggs		Chicks		Total	
	n	%	n	%	n	%
Weather	3	21.4	2	14.3	5	35.7
Disappeared	0	0.0	4	28.6	4	28.6
Vehicles	2	14.3	1	7.1	3	21.4
Other	1[1]	7.1	1[2]	7.1	2	14.2

1 Egg loss due to desertion from observational disturbance.
2 Chick found dead from an unknown cause.

Table 2: Breeding success and failure for damara terns at Struisbaai during the 1995/96 breeding season calculated using Mayfield's (1975) methods.

Stages	Success		Failure		Days Observation
	n	%	n	%	
Incubation	11	56.2	6	43.8	251
Hatching	11	100	0	0.0	n = 11
Fledging[1]	3	27.3	8	72.7	
Total	3	15.3	14	84.7	

1 Calculated using crude method.

Table 3: Number of plasticine "eggs" crushed and missed by vehicles at the three test sites along the Struisbaai beach from 1 December 1995 to 29 February 1996.

Test site	1*	2*	3*
Number crushed	30	25	0
Number missed	880	885	910
Total	910	910	910

* Significantly different (X_2 test $P < 0.001$).

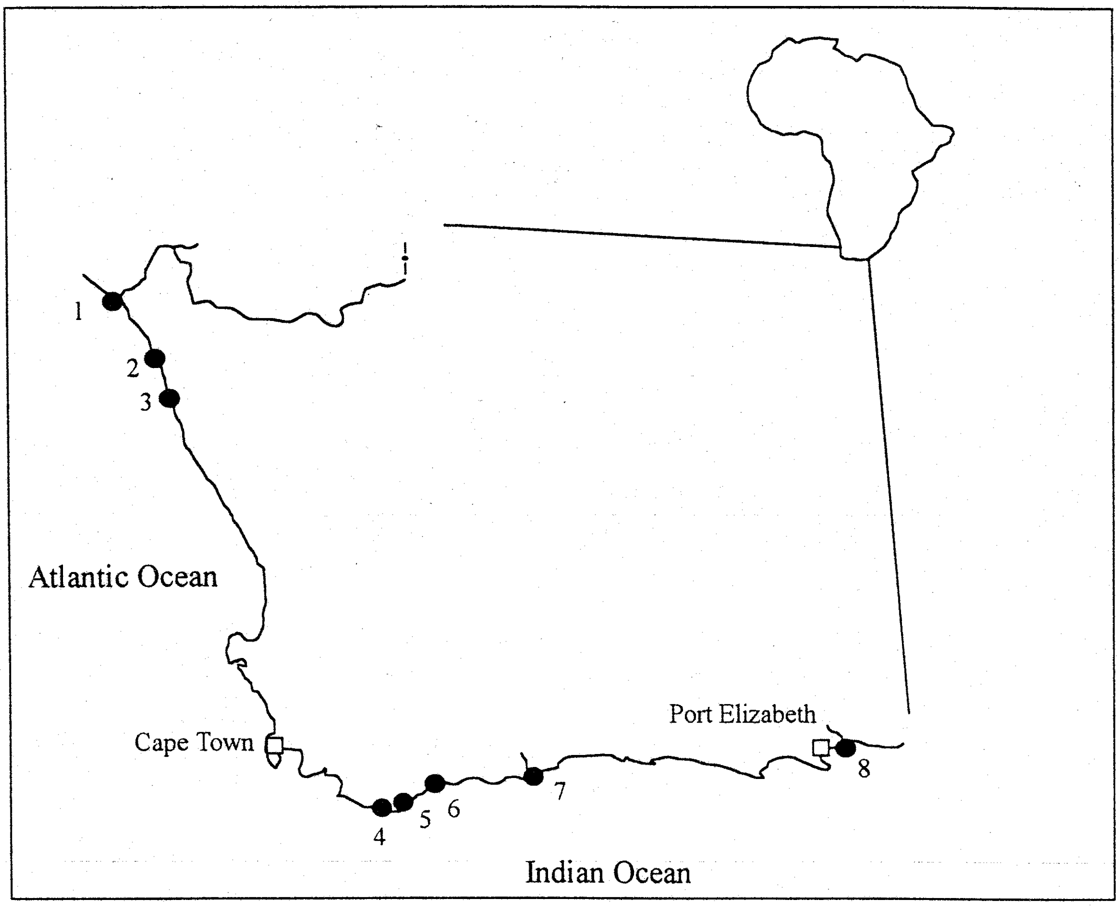

Figure 1: Areas in South Africa, in which damara terns have bred during the past 20 years.

1: Orange River Mouth.
2-3: Area between Port Nolloth and Kleinsee.
4: Brandfontein Private Nature Reserve.
5: Coast between Struisbaai and Arniston.
6: De Nel and De Hoop Nature Reserve.
7: Gourits River Mouth.
8: Alexandria Dune Fields (Algoa Bay).

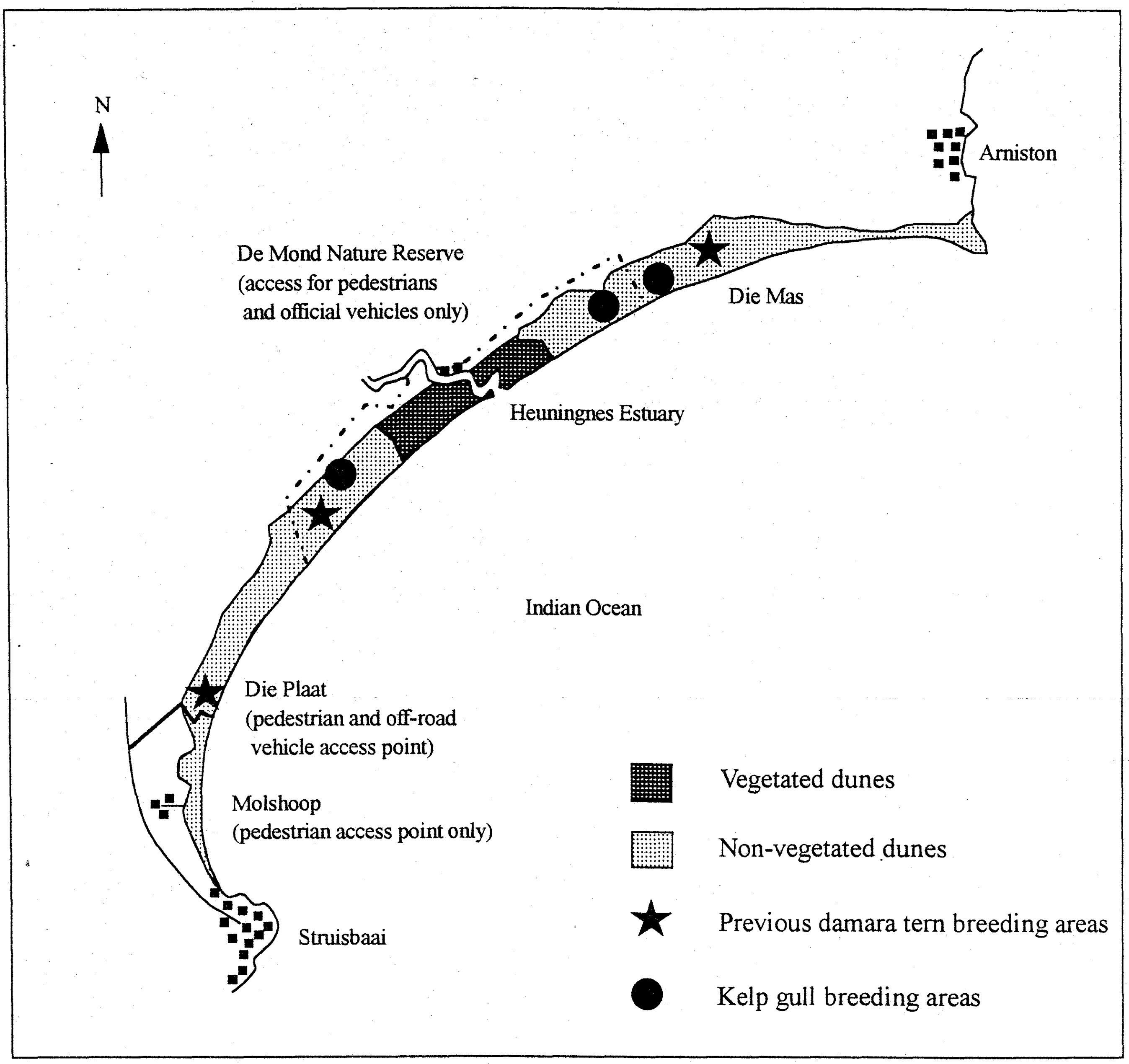

Figure 2: Coastline between Struisbaai and Arniston, south coast South Africa, showing vegetated and non-vegetated dunes, pedestrian and off-road vehicle access points,and kelp gull and previous damara tern breeding areas.

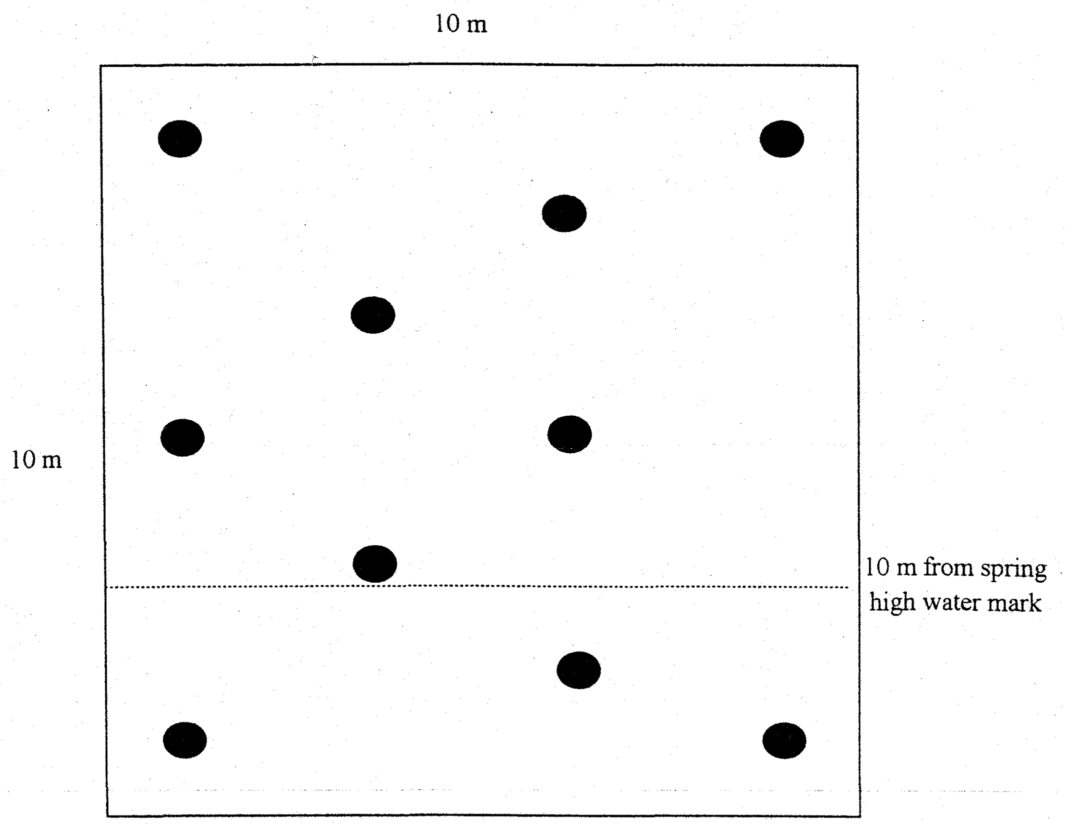

Figure 3: Predetermined placement of 10 plasticine "eggs" in 10 m^2 area at the three test sites.

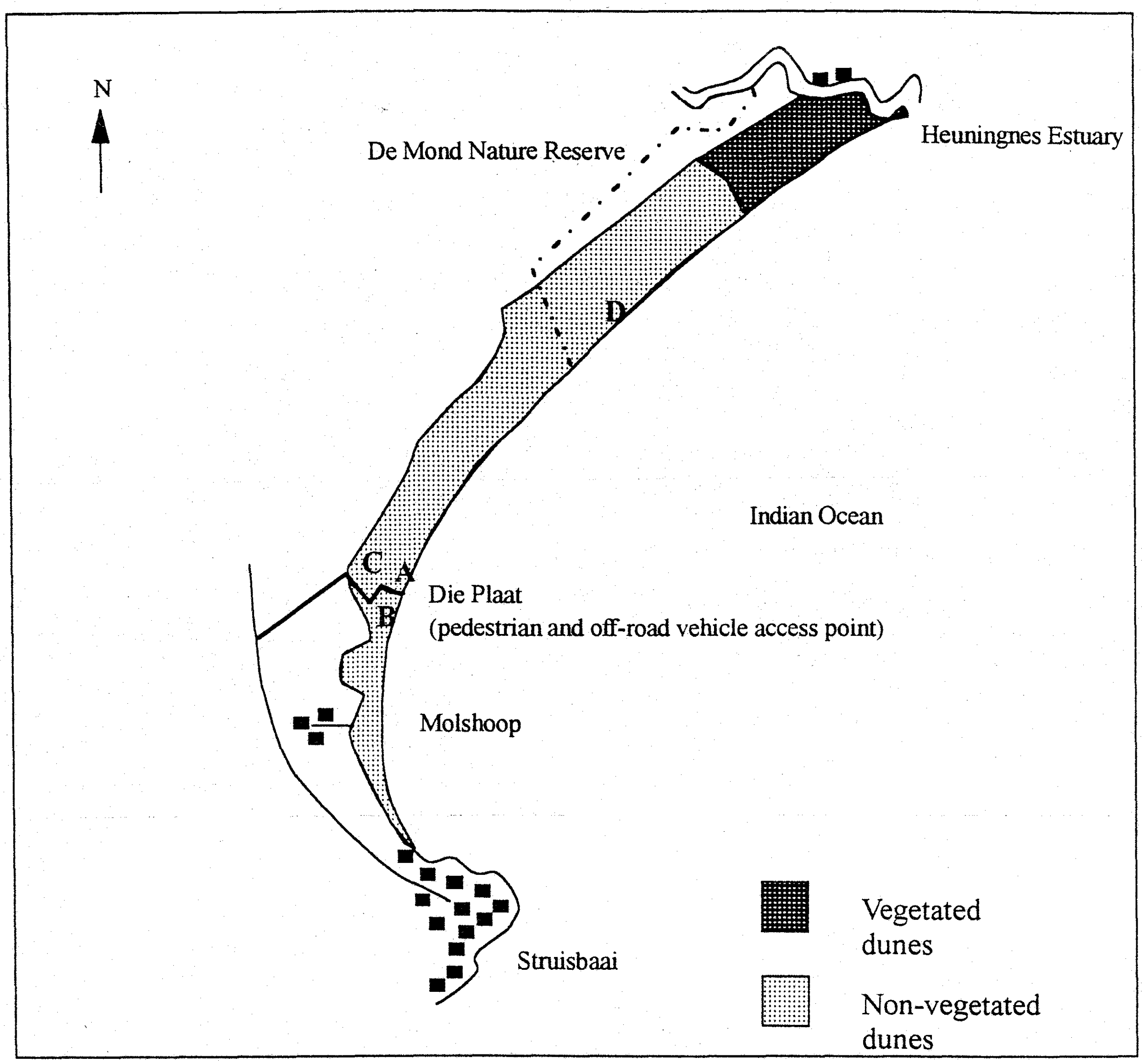

Figure 4: Struisbaai beach showing damara tern breeding areas and plasticine "egg" test sites.

A: Breeding area 1 and test site 1

B: Breeding area 2 and test site 2

C: Breeding area 3

D: Test site 3

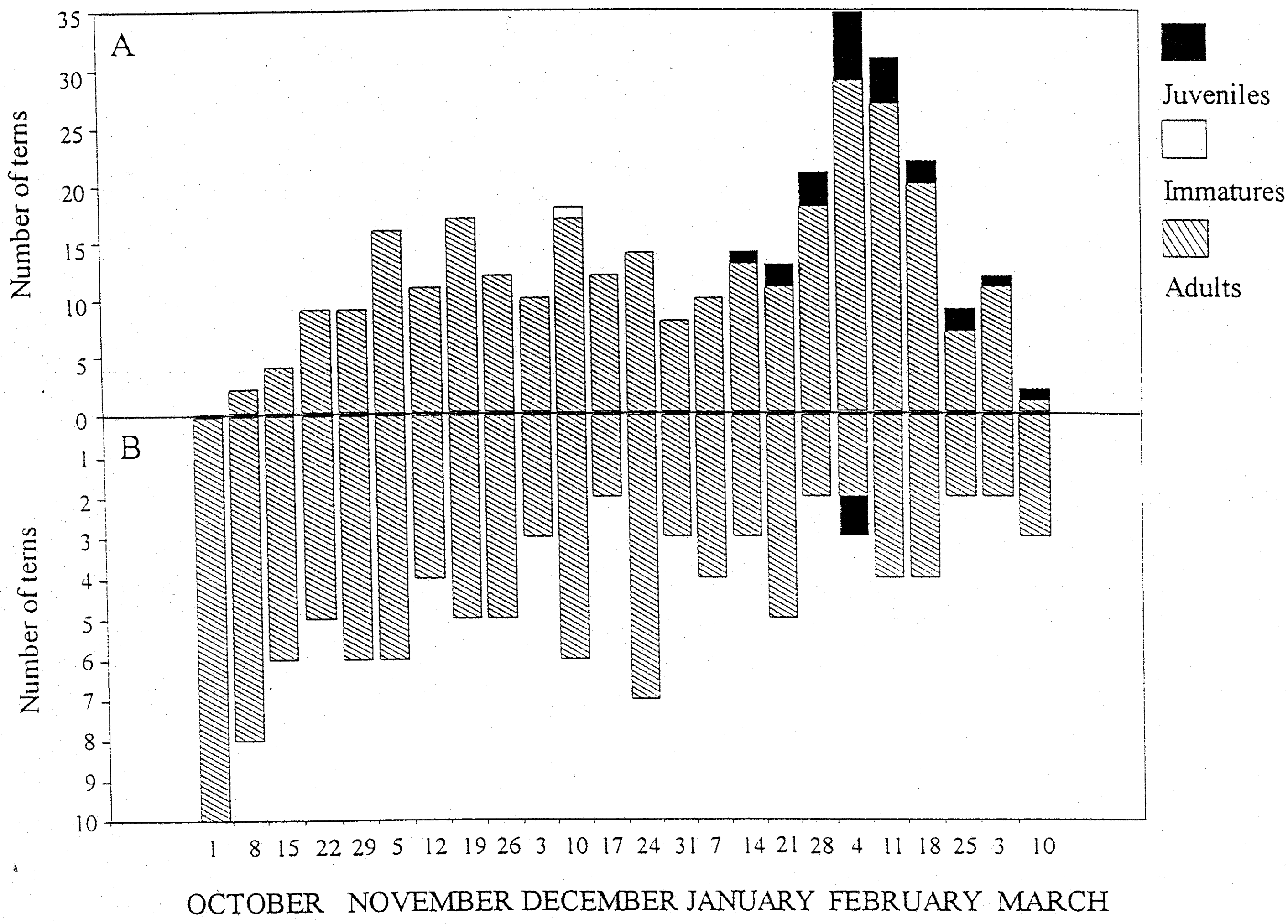

Figure 5: Weekly census values of juvenile, immature and adult damara terns during the 1995/96 breeding season at, (A) Struisbaai beach, and (B) Heuningnes Estuary.
Note different scales on the Y axes.

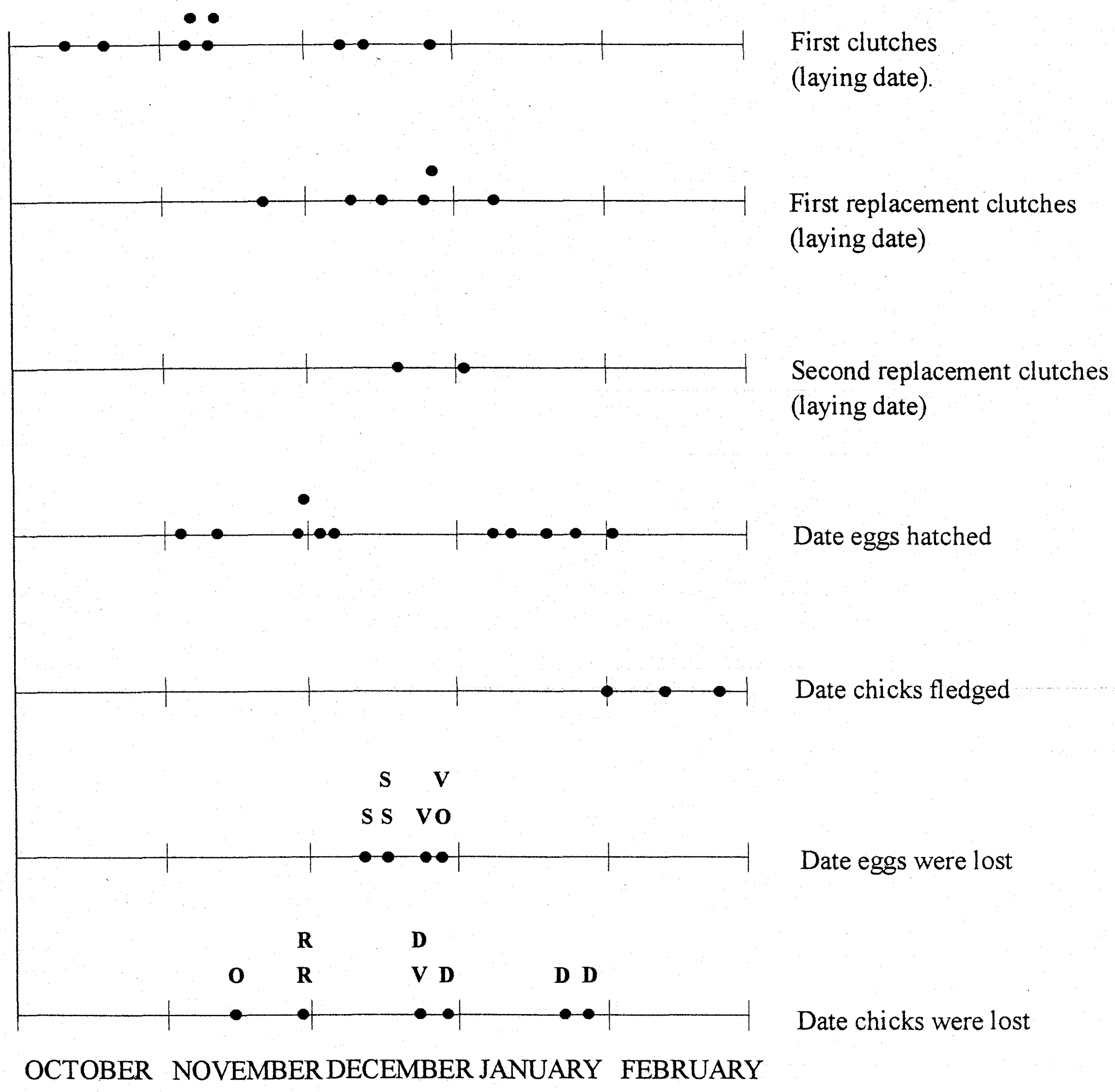

Figure 6: Time series of daily damara tern breeding activity along the Struisbaai beach during the 1995/96 breeding season.

D: Chicks disappeared.
O: Loss attributed to other factors.
R: Loss caused by rain.
S: Loss caused by sand inundation.
V: Loss caused by vehicles.

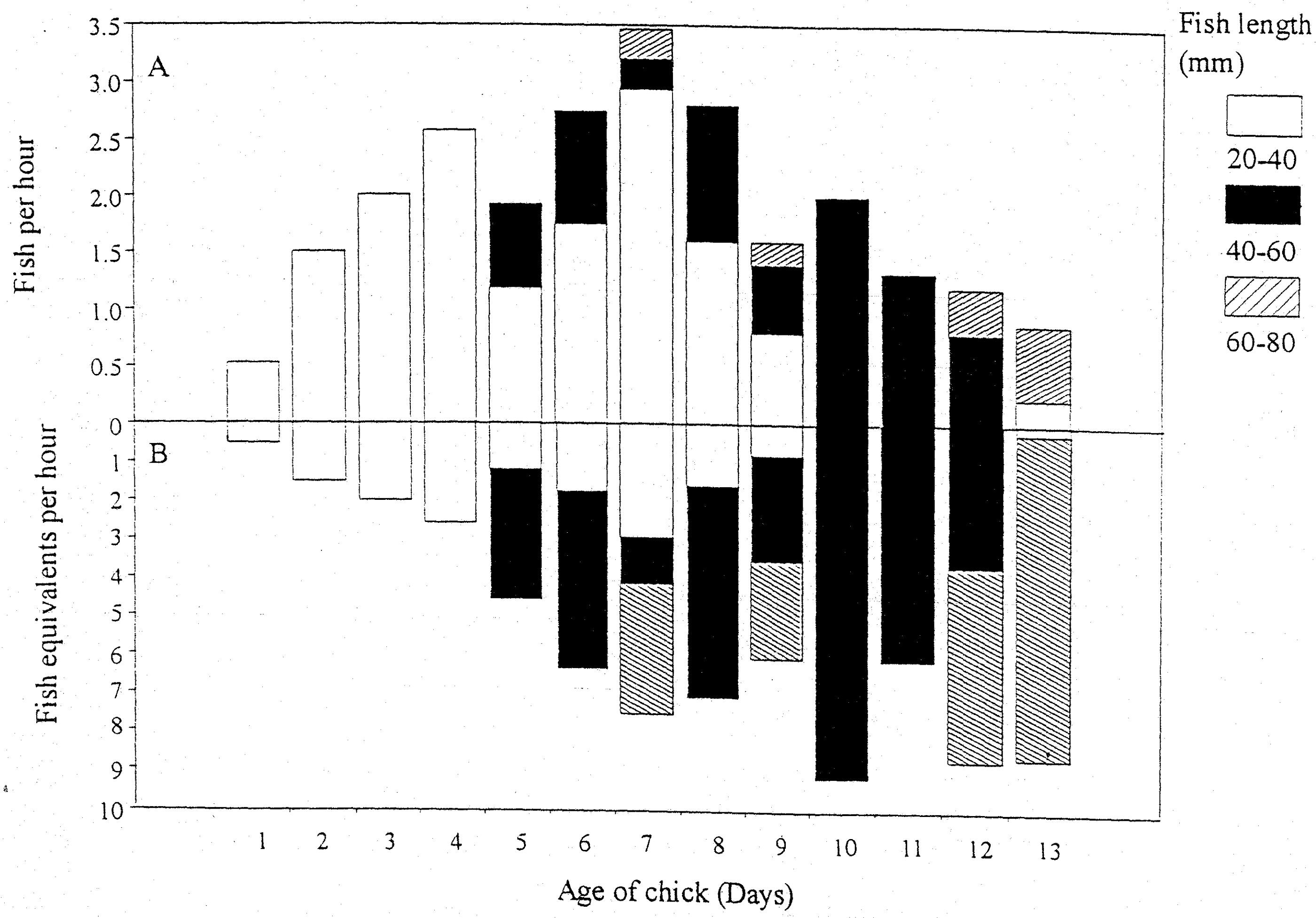

Figure 7: Hourly provisioning rates of damara tern chicks at Struisbaai, (A) number of fish, (B) fish equivalents.

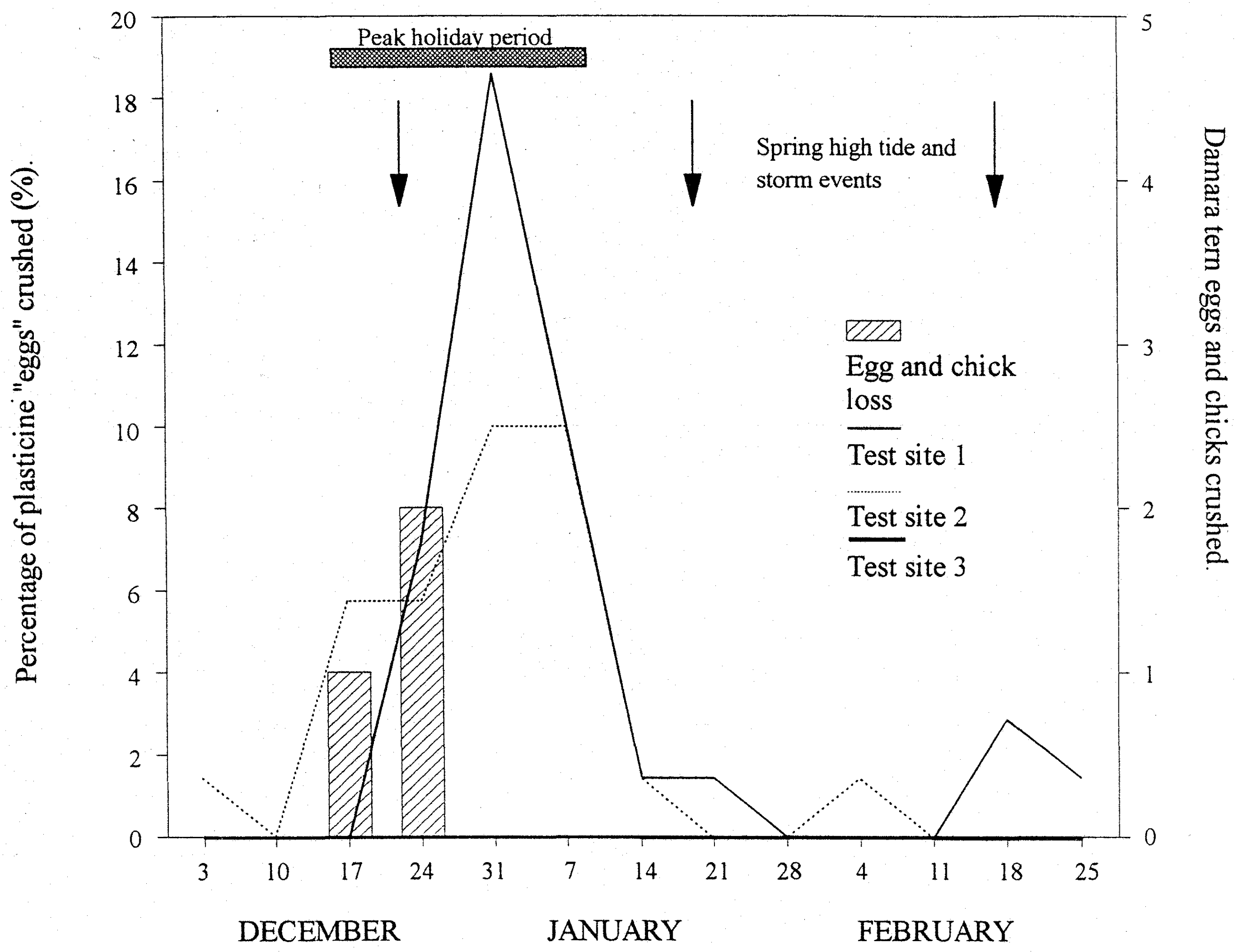

Figure 8: Percentage of plasticine "eggs" at test sites 1, 2 and 3, and number of Damara tern eggs and chicks at breeding area 2, crushed by vehicles during the 1995/96 breeding season.