The distribution and abundance of the humpback dolphin (*Sousa chinensis*) along the Natal coast, South Africa.

by

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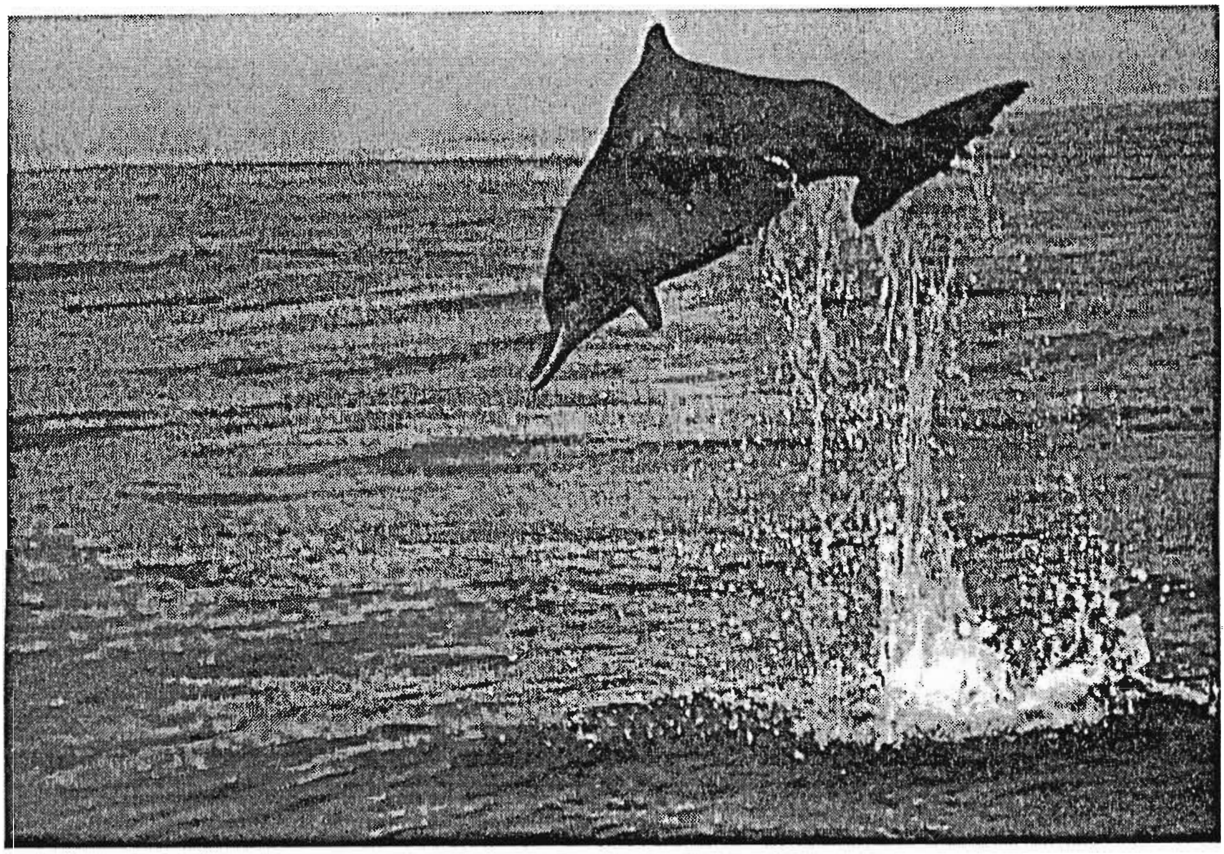

PREFACE

The work described in this thesis was carried out under the auspices of the Department of Biology, University of Natal, Durban from January 1991 to December 1993, and with the supervision of Dr. V.G. Cockcroft at the Port Elizabeth Museum and Professor A.T. Forbes at the Biology Department, University of Natal, Durban.

These studies represent original work by the author and have not been submitted in any form to another University. Where use was made of the work of others it has been duly acknowledged in the text.

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ABSTRACT

Populations of the humpback dolphin in Natal, South Africa, are subject to increasing pressures including capture in the shark nets and habitat degradation, and concern has been raised about the status of the population.

A minimum of 95 humpback dolphins were caught in the shark nets during the period from 1980 to 1992. Capture and sighting records of the Natal Sharks Board revealed a relatively high occurrence of humpback dolphins at Richards Bay. Elsewhere, in southern Natal, the infrequent sightings and captures were attributed to a seasonal occurrence of dolphins, possibly due to temporary movements away from resident areas. Sighting rates reported by the Natal Sharks Board has decreased by 55% from 1984-86 to 1990-92 and may reflect a decrease in the population.

In a photo-identification study, searches took place in ten search areas in Natal. The sighting rates in the different areas revealed a relatively high density of humpback dolphins occurring in north central Natal, from the Tugela River to the St. Lucia estuary (including Richards Bay). This distribution correlated significantly with the turbidity of the water and the width of the inshore continental shelf, and was inversely related to the density of bottlenose dolphins. Within the northern Tugela Bank region, higher densities of dolphins were found surrounding the five river mouths and estuaries.

The Natal population was estimated to be between 161 to 166 animals (95% confidence limits 134 to 229). The annual mortality due to shark net captures approximates 4,5% of the population. Various evidence, including a high mortality rate and a decrease in the annual sighting per unit effort reported by the Natal Sharks Board suggest that the humpback dolphin population in Natal is vulnerable and may be decreasing in size. A proposal is made to reduce the capture rate by relocating shark nets away from the Richards Bay harbour.

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CHAPTER 1

INTRODUCTION

There are 68 recognized species of odontocete cetaceans in the world's oceans and rivers (IUCN, 1991), and many populations are facing increasing pressures. The pressures are varied, and broadly include hunting, incidental capture, pollution and environmental degradation. The causes of these pressures can all be attributed to human activities and it is thus fitting that increasing effort is spent on researching and understanding the population dynamics of these species and the implications of the pressures facing them (Gaskin, 1982).

Research on free-ranging animals can be exceedingly difficult, the causal relationships so ardently sought after in science being subject to uncontrollable environmental influences, such as unpredictable weather changes. Research on wild cetacea is further complicated because observations can usually only be made while the animals are at the surface. The advent of the photo-identification technique (reviewed, for example, by Wursig & Jefferson, 1990) which enables animals to be individually identified and monitored over time has, however, enabled research output to grow rapidly, and genetic studies hold further promise.

Some species are more easy to study, and the available scientific literature on cetacea such as bottlenose dolphins, killer whales and humpback whales is relatively large. Other species, including the humpback dolphin, are relatively rare, particularly cryptic (Johnson & Norris, 1986), or occur in developing countries where research is not a priority, and scientific data are therefore limited.

The determination of the status of these little-known species is of particular importance, as population depletion may go un-noticed and un-challenged. Currently studies are underway which aim to describe the taxonomy of the humpback dolphin, the genetic structure of the population in Natal, and the biology of the dolphin and the reproductive periodicity. This study was designed to provide field data to complement these studies.

1.1 GENERAL REVIEW

1.1.1 Taxonomy

The taxonomic status of the humpback dolphin is unresolved: Between two and five nominal species of the genus *Sousa* have been proposed, and the acceptance of these species varies. The conservative approach (Mitchell, 1975; Rice, 1977; IUCN, 1991) is adopted for this thesis:

S. chinensis (Osbeck, 1765) as the Indo-Pacific species,

S. teuszii (Kukenthal, 1892) as the West African form.

Should it be ascertained that there are more species in the genus *Sousa*, each with separate distributions, conservation implications would necessarily be more grave.

1.1.2 Distribution

The humpback dolphin *Sousa* sp. occurs in coastal, tropical waters extending into higher latitudes in areas of relatively high water temperature. The Indo-Pacific humpback dolphin *S. chinensis* is widely distributed in the inshore waters of the Indo-Pacific Ocean, and ranges from South Africa to the East China Sea and Australia (Ross, Heinsohn & Cockcroft, 1994; IUCN 1991). The West African or Atlantic humpback dolphin *S. teuszii* occurs in coastal waters from Cameroon to Senegal and Mauritania (Maigret, 1981; IUCN, 1991; Ross *et al.*, 1994).

1.1.3 Habitat

Saayman & Tayler (1979) found that humpback dolphins at Plettenberg Bay, in the Eastern Cape, occur less than one kilometre offshore. On the seaward side of the Robberg peninsula, dolphin groups remained within 250 m of the shore and just seaward of the breaking waves. In the Bay, where the seabed was sandy with outcrops of isolated reefs, humpback dolphins moved systematically from one outcrop to the next, lingering over the reefs where they remained submerged for comparatively long periods. Cockeron (1990), working in Moreton Bay, Queensland, reported that while the humpback dolphin did not occur close to the shore, the mean maximum depth that the dolphin was found in was 9,0 m. Apart from this, little is known of the apparent habitat preferences of the dolphins.

Although relatively high densities are frequently reported in areas around river mouths, tidal creeks and mangrove channels (Pilleri & Gihr, 1972; Zbinden, Pilleri, Kraus & Bernath, 1977; Pilleri & Pilleri, 1979; Maigret, 1981; Roberts, Khan & Knuckley, 1983; IUCN, 1991), these reports are anecdotal, and none provide absolute densities. In southern China individuals may swim up rivers for several kilometres (Wang Peilie, 1985). Humpback dolphins are reported to occur in areas of high water turbidity (Pilleri & Gihr, 1972; Zbinden *et al.*, 1977; Pilleri & Pilleri, 1979), consistent with estuarine areas having high sediment loads. However, in the Eastern Cape, the humpback dolphin is apparently resident in relatively clear water with a clarity of up to 24 m (Saayman & Tayler, 1979; Karczmarski, pers. comm.).

1.1.4 Social structure

Humpback dolphins in the Eastern Cape occur in small groups, ranging from one to 25 animals and averaging 6,9 (Saayman & Tayler, 1979). Elsewhere, reported group sizes generally lie within this range (Pilleri & Gihr, 1972; Zbinden *et al.*, 1977; Pilleri & Pilleri, 1979; Maigret, 1981), although an exceptional aggregation of 50 animals was reported in the Indus creek (Pilleri & Pilleri, 1979). According to Saayman & Tayler (1979), humpback dolphin groups are characterized by their temporary nature and fluctuating membership.

Five age classes, differentiated by size, colouring and behaviour, were described by Saayman & Tayler (1979).

1) small calf: young calves off-white in colour and approximately one third the length of adults. They were closely accompanied by an adult. On surfacing to breathe the small calves appeared not to be able to judge the surface, and would frequently "overshoot".
2) large calf: larger calves, approximately half the length of adults, their colouration a deeper grey. The large calves remained in the vicinity of adults. Their behaviour was typical of adults, and included aerial somersaults and inverted postures typical of mating.

3) juvenile: two thirds the length of adults and uniform grey in colouration. Juveniles frequently formed subgroups which remained in the general vicinity of adults.

4) greyback: sub-adult animals not yet of maximum length or girth, but displaying full independence of movement and association with other dolphins. Behaviourally the greybacks were indistinguishable from "adults".

5) whitefin: large animals, characterized by the whitening of the dorsal fin and frequently displaying scars on the fin and hump.

The average age class composition of groups was 11%, 10%, 23%, 37% and 20% of the total, respectively. Immatures tended to associate with groups containing more than one adult, and lone animals and pairs were usually adults.

Based on frequent re-sighting of three identified adults in Plettenberg Bay, South Africa, Saayman & Tayler (1979) suggested that the groups utilized a familiar and limited home range. The authors estimated the total population resident in the Plettenberg Bay area to be approximately 25 animals. Heinsohn, Goudberg & Marsh (1980) reported that the Indo-Pacific humpback dolphin occurred throughout the year along northern Queensland, Australia. Based on differing seasonal densities, Maigret (1981) suggested that there may be a seasonal movement of the west African humpback dolphin in summer, from Senegal to Mauritania. The apparent movement may, however, be due to a relatively small seasonal shift in the population centres.

1.1.5 Behaviour

Four categories of activity were described by Saayman & Tayler (1979), *viz.* group progression, feeding, resting and social activities.

1) Group progression: This was defined as consistent, directional movement. The group moved rapidly and in the same direction from one area to another without evidence of feeding or social activities. Group movements were often sustained for long periods (until the dolphins disappeared from view along the coastline). The progression rate averaged 80,6 $\pm$ 5,5 m/minute.

2) Feeding: Here the groups of humpback dolphins dispersed widely, and appeared to capture fish on an individual basis. Occasionally the predatory behaviour of the dolphins was characterized by long-jumping and high speed chasing. Feeding generally took place over rocky areas and frequently along an unsheltered coastline. The time spent feeding increased on the rising tide.

3) Resting: The dolphins moved slowly in a compact group with a drifting or gliding motion, rising slowly to breathe while circling over the same area.

4) Social behaviour: This phase was marked by extensive bodily contact, inverted swimming, somersaulting, leaping and chasing. Apparent play with animate and inanimate objects was occasionally recorded. The resting and socially active phases were usually seen in the sheltered, sandy Plettenberg Bay.

In Senegal, humpback dolphins moved into the mangrove channels with the rising tide, and returned to the sea with the ebb (Maigret, 1981). Peddemors & Thompson (in press) report that in Mocambique, humpback dolphins chased fish onto sandbanks to feed on them. Humpback dolphins in South Africa fed on littoral and estuarine associated fish, and on demersal species primarily associated with reefs (Cockcroft & Ross, 1983; Barros & Cockcroft, 1991).

Corkeron (1990), working in Moreton Bay, Queensland, found mixed groups of bottlenose (*Tursiops truncatus*) and humpback dolphins (*Sousa chinensis*) more frequently than he found only humpback dolphin groups. The mixed groups were, however, seen only in association with trawlers, this possibly because the trawlers created "food patches". Corkeron reported that bottlenose dolphins appeared to be dominant over humpback dolphins, possibly because the mixed groups were comprised of mostly bottlenose dolphins. Saayman & Tayler (1979) observed humpback dolphins both travelling and playing with bottlenose dolphins, and apparently integrated into the bottlenose dolphin groups. On other occasions, however, the researchers observed humpback dolphins avoiding bottlenose dolphins and lone humpback dolphins being aggressively chased by bottlenose dolphins.

Humpback dolphins are characteristically wary of boats, and rarely permit a close approach (Pilleri & Gihr, 1972; Zbinden *et al.*, 1977; Maigret, 1981; Roberts *et al.*, 1983; Ross *et al.*, 1994). The avoidance reaction of the dolphins is to split up into small groups or single animals, and there are frequent underwater direction changes (Ross *et al.*, 1994).

1.1.6 Human influence

The inshore distribution of the humpback dolphin makes it vulnerable to human activities in the coastal zone, particularly those related to fisheries. Gill net mortalities are widespread throughout its range (Ross *et al.*, 1994). Dolphins are usually not captured deliberately. In Natal, South Africa, and Queensland and New South Wales, Australia, humpback dolphins are captured in shark nets set around bathing beaches (Cockcroft, 1990a; Ross *et al.*, 1994). Incidental captures have been recorded in West Africa (Maigret, 1981), Madagascar (Cockcroft & Krohn, in press; Ross *et al.*, 1994), Djibouti, the Arabian Gulf (Ross *et al.*, 1994), the Indus delta (Pilleri & Pilleri, 1979), the southwest coast of India (Ross *et al.*, 1994), and Australia (Bannister, 1977; Harwood & Hembree, 1987). Deliberate capture of humpback dolphins has been reported in Mocambique (Cockcroft, pers. comm.).

With the burgeoning human population and industrialization particularly of the developing countries, the coastal marine environment is subject to increasing habitat disturbance in the form of effluent discharge, over-fishing, land reclamation and the pollution and damming of rivers. These direct and indirect pressures on humpback dolphins throughout their range have caused widespread concern (Pilleri & Pilleri, 1979; Cockcroft, 1989; Ross & Best, 1989; IUCN, 1991).

1.2 STUDY AREA

1.2.1 Physical geography

Southern Africa, landlocked in the Gondwanaland super-continent prior to the Jurassic Period, developed a coastal belt only on the break up and dispersal of the continents in the Jurassic and Early Cretaceous periods. The present continental shelf off the Natal province is narrow and steep, having formed from shearing between it and the present

Falkland plateau (Martin & Flemming, 1988). The Agulhas current, a warm, southward-flowing current, runs just offshore of the shelf break (Martin & Flemming, 1988), markedly affecting the physical and biological parameters of the shelf waters (Flemming & Hay, 1988; Schumann, 1988b).

The Natal coast (Figure 1.1) stretches for approximately 550 kilometres from Mocambique (26°52'S/32°54'E) to the Transkei (31°05'S/30°11'E) border. The coastline is relatively straight, and there is little protection from prevailing weather or sea conditions. The surf zone in Natal is described as having high physical energy (Van der Elst, 1988).

The Natal coastal belt has a humid subtropical climate with a warm summer (Schumann, 1988a), the prevailing winds blowing parallel to the coast. Rainfall in Natal occurs predominantly during the summer months - November to March (Hunter, 1988), and annual precipitation varies between 1000 and 1100 mm. There are 73 rivers in Natal, the majority having outlets to the sea in southern Natal. The largest river system is the Tugela River, followed by the St. Lucia Estuary (Flemming & Hay, 1988), both in north-central Natal. In winter, with reduced outflow, sandbars develop and seal off the majority of the rivers (Schumann, 1988a). However, in the Richards Bay/Cape St. Lucia portion of the coastal belt the winter rainfall is relatively high (Hunter, 1988), and rivers in this region may remain open for relatively longer.

The salinity of the sea averages 35,3‰ (Van der Elst & Fennessy, 1990), with localized reductions occurring near the mouths of "large rivers" (Schumann, 1988b; Van der Elst, 1975). The average annual sea surface temperature varies by approximately 4°C, with a high of about 25°C in February (Schumann, 1988b). The tidal range is between 1 and 2 m (Tinley, 1985).

Humpback dolphins feed on littoral, demersal and estuarine species, and are consequently found in shallow water. The inshore area, here taken as extending to the 15 m isobath, is relatively narrow for most of Natal, varying between 0,3 m and 1,5 km at spring low tide (South African Navy charts). There are reefs further offshore with pinnacles extending within 15 m of the surface at Sodwana Bay, in northern Natal, and at Aliwal

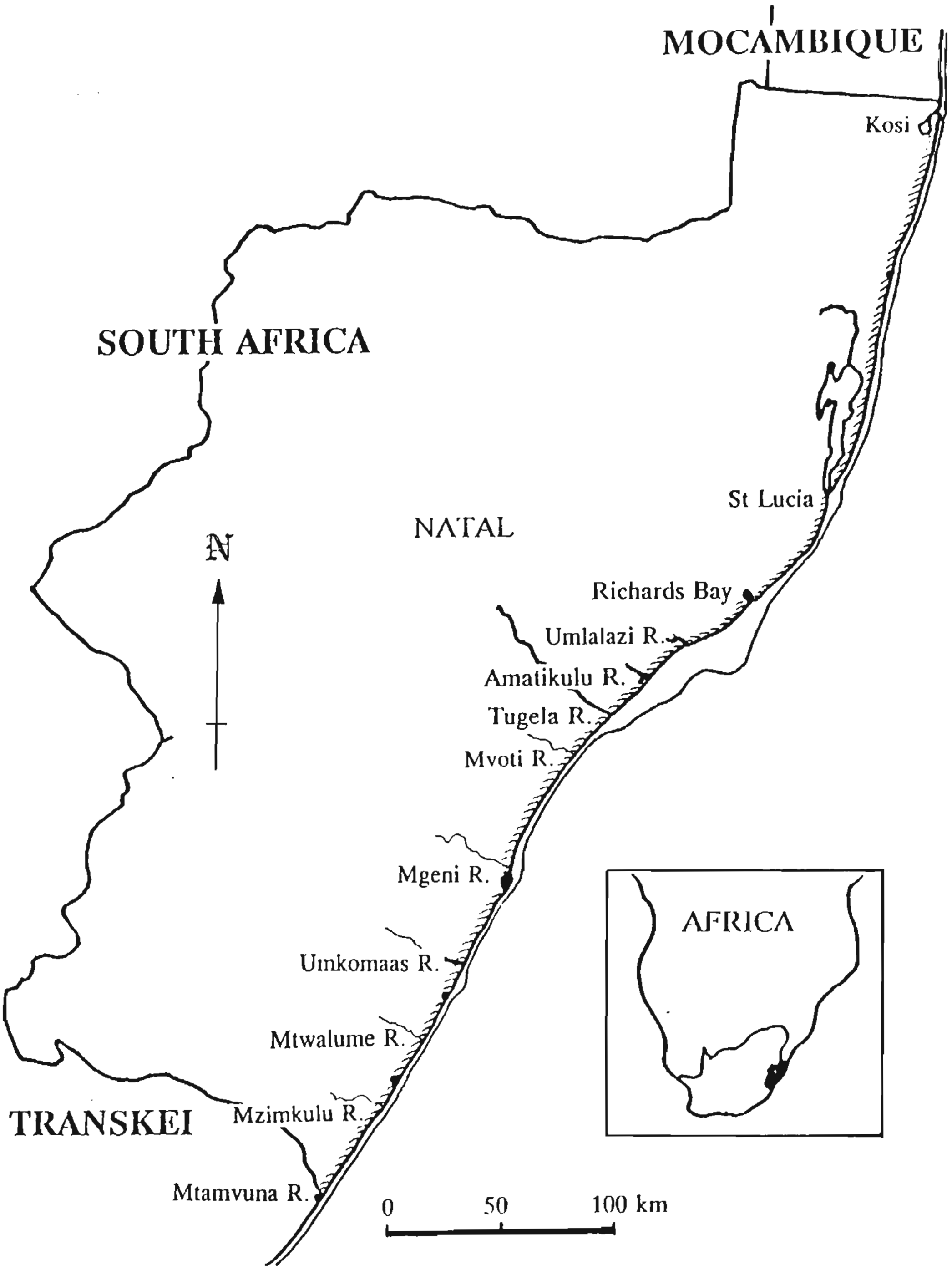

Figure 1.1 The Natal coast, South Africa. The position of the 15 m isobath and the major river and estuarine systems are shown.

shoal, just south of the Umkomaas River (Fig. 1.1). From the Tugela River north to the Nhlabane River (98 km), however, the 15 m isobath extends further offshore, the shelf reaching a maximum width of 8,3 km off the Port Durnford beacon. The sediment pattern along this bank indicates vigorous wave-induced turbulence at the seabed (Flemming & Hay, 1988), and the inshore waters in this area are generally turbid (Van der Elst, 1975; Schumann, 1988b; Cockcroft, 1990a).

The superficial sediments along the continental shelf consist primarily of sand, with relatively small amounts of gravel and mud. Fluvial sediments, have, in recent years, greatly increased, owing to poor farming practices (Flemming & Hay, 1988), the summer rains discharging large quantities of sediment to the sea via the rivers (McClurg, 1988; Schumann, 1988a).

The Agulhas current is the most important factor controlling sediment transport and distribution on the Natal continental shelf (McClurg, 1988). Most of the fine sediments emanating from the rivers remain in suspension and are transported off the shelf, although current eddies in the shelf section between Durban and Richards Bay (Bang & Pearce, 1978; Flemming & Hay, 1988) have allowed mud depocentres to develop at the Tugela River and the St Lucia estuary. Sediment type is probably the most important factor determining the distribution of the benthos off Natal (McClurg, 1988). In addition to the shelf benthos, the Agulhas current is also influential in the transport of tropical and subtropical species southwards (McClurg, 1988; Van der Elst, 1988).

1.2.2 Coastal fauna

As humpback dolphins are primarily piscivorous (Cockcroft & Ross, 1983; Barros & Cockcroft, 1991; Ross *et al*, 1994) the habitat type and associated prey species probably influences both the distribution and density of the humpback dolphin.

There are no true coral reefs off the Natal coast, although north of St Lucia most of the offshore reefs are topped with prolific growths of coral (McClurg, 1988). South of St Lucia the abundance of corals diminishes rapidly, owing to the high loads of suspended solids preventing light penetration (McClurg, 1988) and/or decreasing water temperatures (Van der Elst, 1988). However, McClurg (1988) reported that "good" growths of coral were evident on the Aliwal shoal, in southern Natal.

The Natal ichthyofauna consists predominantly of species of tropical Indo-Pacific origin (Van der Elst, 1988). Most of the fish of Natal have a distinctly seasonal occurrence (Van der Elst, 1988). During the summer, tropical species are more abundant. The winter species are either endemic or migrate from temperate Cape waters to spawn once temperatures drop below 21^{0}C (Van der Elst, 1988). The winter migration of the pilchard *Sardinops ocellata* and associated game fish, sharks and dolphins frequently assumes massive proportions, and may be "the most significant biological event that occurs annually in this ecosystem" (Van der Elst, 1988).

1.2.2.1 The influence of the shark fishery on coastal fauna

Anti-shark gillnets are set at popular beaches as a means of protecting bathers from shark attack. The fishery was designed to reduce the population of large sharks (Van der Elst, 1979) with the consequent effect of reducing shark interactions with humans (Davis, Cliff & Dudley, 1989; Dudley & Cliff, 1993b).

The gillnets were first installed off beaches in Natal in 1952 (Davis, Cliff & Dudley, 1989), and the number of netted beaches increased rapidly during the 1960's and 1970's (Cliff, Dudley & Davis, 1988). By 1988 there was a total of 44 km of nets set at 45 beaches from Mzamba in northern Transkei to Richards Bay (Cockcroft, 1990a).

From 1966 to 1970 there was a steep decline in the shark catch per unit effort (Dudley & Cliff, 1993b), indicating a drastic decrease in the population of large sharks. After the 1970's the CPUE stabilized and although there was an annual fluctuation there was little or no trend. This has been interpreted as the removal of the resident community of sharks (1966 - 1970) followed by the harvesting of immigrants (Dudley & Cliff, 1993b). Approximately 1200 - 1400 large sharks are captured annually (Dudley & Cliff, 1993b). In addition to sharks, batoids, sea turtles, teleosts and dolphins are also captured (Cockcroft, 1990a; Dudley & Cliff, 1993b).

Although a possible decrease in predation on dolphins has occurred, implications of the removal of large sharks may be more widespread: A proliferation of small sharks was recorded from 1966 to 1976, and was partially attributed to the capture of larger predators (Van der Elst, 1979 & 1989). This proliferation may have increased the competition for teleost food resources (Van der Elst, 1979; Compagno, Ebert & Smale, 1989).

1.3 PRESSURES ON THE HUMPBACK DOLPHIN POPULATION IN NATAL

The most obvious pressure on the humpback dolphin in Natal is that caused by the shark fishery. From 1980 to 1988 a minimum of 67 humpback dolphins was caught in shark nets, giving a minimum annual average of 7,4 dolphins (Cockcroft, 1990a). From extremely limited data, Ross (1982) estimated the population size at roughly 200 animals. This estimate was used by Cockcroft (1990a) to produce an estimate of the annual capture at 4% of the population, which if correct, may have a substantial impact on the population. However, a precise data set is required on which to base conservation management policies.

Shark predation has also been suggested as an important component in the mortality of dolphins in Natal (Cockcroft, 1990b), where a minimum of 28% of humpback dolphins captured in the nets from 1980 to 1987 had scars consistent with previous shark bite wounds. Dudley & Cliff (1993b) have suggested, however, that there has been a reduction in predation due to a 75% decrease in the population of large sharks since the installation of shark nets.

The commercial and recreational teleost fisheries in Natal have greatly increased in the last 50 years (Van der Elst, 1979; 1988), and a broad change in species composition of the catch has occurred, the over-fished species all being endemic to South African waters (Van der Elst, 1988). The fact that total landings have not risen, despite the rapidly increasing fishing effort, has been suggested by Van der Elst (1988) and Garrat (pers. comm.) to indicate a collapsing stock. As humpback dolphins are primarily piscivorous (Barros & Cockcroft, 1991), competition from the recreational and commercial fisheries may be reducing some available food resources. At least three prey items of humpback dolphins (*Pomadasys commersonii, Rhabdosargus* sp. and various seabreams; Barros & Cockcroft, 1991) show signs of population decrease (Van der Elst, 1988; 1989), and restrictions have been imposed on the number and size caught by anglers (Penney, Buxton, Garratt & Smale, 1989). Reduction in one prey species could conceivably promote an increase in others, however, and as the humpback dolphin has a fairly broad spectrum of prey items, it is not possible to accurately determine the effect of the increased fishing pressure.

Industrial and domestic effluent disposal occurs at 47 recognized points on the Natal coast, the total volume discharged exceeding 600 000 m^3/day (Connell, 1988). Other sources of marine pollution in Natal are urban and rural run-off, which can include herbicides, pesticides, hydrocarbons and metals, marine dumping or leakage from ships and offshore platforms, and particle deposition or gas exchange from the atmosphere (Moldan, 1989). The long term effects on the surrounding habitat are not yet known, but elsewhere numerous reports of habitat disturbance have been recorded following extreme coastal marine pollution (Butler, Childress & Wilson, 1972; Nitta, 1972; Wastler & Wastler, 1972).

Dolphins are among the top predators in the food chain, and toxic chlorinated hydrocarbons, derived principally from pesticide and industrial pollution, accumulate in the blubber (Addison, 1989). Under conditions of food stress, including pregnancy and lactation, the blubber is utilized as an energy source, and the toxic residues are mobilized, with possibly fatal consequences to the animal, its foetus or the suckling offspring (Addison, 1989; Cockcroft, 1989; Cockcroft, De Kock, Lord & Ross, 1989; Cockcroft, Ross, Connell, Gardner & Butler, 1991). Additionally, reproductive impairment in marine mammals has been correlated with high organochlorine levels (Gaskin, 1982; Subramanian, Tanabe, Tatsukawa, Saito & Miyazaki, 1987; Addison, 1989). Organochlorine residue levels of humpback dolphins caught in the nets in Natal during the 1970's and 80's were the highest of any marine mammal off the South African coast

(Connell, 1988; Cockcroft, 1989; Cockcroft *et al.*, 1989), consequently indicating a possible impact on the mortality and reproductive rates of the dolphin.

Assuming an annual increase of one growth layer group (GLG) in teeth, Cockcroft (1989) estimated that humpback dolphins in Natal reach sexual maturity at the age of ten and a calving interval of approximately three years. The annual birth rate (i.e. the proportion of births relative to the number of animals in a population per year) of 0,10 has been roughly estimated from observation of the proportion of calves in the population in Plettenberg Bay, Eastern Cape, South Africa (Saayman & Tayler, 1979; Perrin & Reilly, 1984). This value falls within the range of estimates of gross annual reproductive rates (the unbiased estimate of the birth rate per year) for delphinids of between 0,026 and 0,144 (Perrin & Reilly, 1984). The rate of increase of delphinid populations (ie. the net reproductive rate per year) ranges from 0,017 to 0,032 per annum. Without a reasonably accurate estimate of the population, however, the status of the humpback dolphin cannot be reliably assessed.

In a preliminary genetic study, Smith (1990) electrophoretically examined 16 liver samples taken from net captured humpback dolphins in Natal. She found three polymorphisms amongst the 23 protein loci examined. Statistically analyzing the zymograms, she found significant inbreeding coefficients (F_{IS} = 0,165) which indicated high levels of inbreeding in the population. While these results should be viewed with caution because of the small sample size and the relatively few polymorphic loci found (further studies are underway), they potentially indicate that immigration into Natal is limited. If this is the case, any depletion of the population may not be offset by immigration.

Although humpback dolphins are known to occur in the inshore waters along the Natal coast, very little is known about the structure and dynamics of the population. Thus, while it is evident that the humpback dolphin population in Natal is affected by man primarily through shark net captures, the status of the population remains unknown.

1.4 STUDY AIMS

The aims of this study were therefore to:

1. Estimate the size of the population in Natal.
2. Quantify group structure, number of calves, juveniles and adults, based on the relative length of individuals.
3. Provide estimates of school turnover and individual associations within schools, allowing an assessment of school discreetness.
4. Provide data on movement patterns and the extent of 'home range'.
5. Provide data on reproductive seasonality and periodicity, which can be gauged from calf occurrence and association with identified adults.
6. Quantify habitat use by relating biological, behavioural and distributional data to environmental and physical parameters, particularly those in the region of shark nets.
7. Provide an assessment of the status of the humpback dolphin population in Natal waters and make management recommendations.

CHAPTER 2

THE NATAL SHARK NET FISHERY: CAPTURES AND SIGHTINGS OF HUMPBACK DOLPHINS, 1980 TO 1992.

2.1 INTRODUCTION

Following a spate of shark attacks along the Natal coast in the 1940's, anti-shark nets were installed at Durban in 1952. More nets were installed in different locations after "Black December" in 1957, when further attacks had disastrous effects on the local tourist industry (Davis, Cliff & Dudley, 1989). The Natal Sharks Board, a non-commercial institution, was created in 1964 to safeguard bathers against shark attack, and has been in charge of netting operations since then. By 1990 there were shark nets at 45 different beaches from Mzamba in the northern Transkei to Richards Bay (Cockcroft, 1990a). The gill nets were monitored and meshed daily by officers assigned for varying lengths of time to a specific area. Individual nets were removed and immediately replaced every three to ten days to prevent algal fouling, and remained in the same positions throughout the year. This provided the background for potential consistency of observation not readily available in commercial fisheries.

Unfortunately the nets are not shark specific, and sea turtles, batoids, teleosts and dolphins are also captured (Cockcroft, 1990a; Dudley & Cliff, 1993b). Three species form the majority of the dolphin by-catch in the gill nets. These are the common *Delphinus delphis*, bottlenose *Tursiops truncatus* and humpback *Sousa chinensis* dolphins, contributing 46%, 42% and 10%, respectively, of the annual cetacean catch of approximately 73 animals (Cockcroft, 1990a). The effect of the catch on the pelagic common dolphin population is thought to be minimal (Cockcroft, 1990a). The humpback and bottlenose dolphin populations occur throughout the year, however, in the inshore waters along the Natal coast (Ross, 1982; Ross, Cockcroft, Melton & Butterworth, 1989). Their high degree of isolation (Durham, 1990; Smith, 1990) and relatively low numbers (Ross, 1982; Ross *et al.*, 1989) suggests that the pressures on these populations may cause depletion (Cockcroft, 1990a; Peddemors, 1993).

As the humpback dolphin is uncommon and shy (Zbinden, Pilleri, Kraus & Bernath, 1977; Ross, Heinsohn & Cockcroft, 1994; IUCN, 1991), there is relatively little available scientific literature on this species (IUCN, 1991). The records on the capture and sighting of dolphins by the Natal Sharks Board form a relatively long term data set, which are of great value. This chapter documents the capture of humpback dolphins in the shark nets from 1980 to 1992, and the sightings reported by the field staff of the Natal Sharks Board from 1984 to 1992.

2.2 METHODS

The net installations in Natal are situated predominantly in southern Natal, from Mzamba to Zinkwasi, at an average distance of 5,4 km apart. The northern-most netted installation, Richards Bay, is relatively isolated, situated approximately 78 km north of Zinkwasi.

The nets are made of 3 mm black multifilament nylon, have a mesh size of 25 cm and are 6,3 m deep. As the length of the nets changed during the study period and are currently 106m long, the nets are described in 106 m units. From 1980 to 1992 nets were set at 45 beaches from Mzamba ($31^0$05'S / $30^0$11'E) to Richards Bay ($28^0$48'S / $32^0$06'E) (Table 2.1). The nets were set parallel to the coastline in a water depth of approximately 12 m, usually between 400 m and 800 m from the shore. The netting effort increased during the study period from 346 to 419 net units (Table 2.2).

Nets are inspected daily, weather permitting. Live captured dolphins are released, dead animals are dumped at sea if in a state of decay and otherwise returned to shore. Captured and dead dolphins were stored at -20^0C until analyzed for research purposes. The NSB capture data for the period from 1980 to 1992 consisted of the date and location of captured humpback dolphins, and the Port Elizabeth Museum supplied data on the sex and body length of those animals returned for storage. Sighting records (1984 - 92) of the NSB gave the location of sighting, and, after 1987, the size of the group seen.

Table 2.1 Locality, year of installation and number of shark nets (106 m units) along the Natal coast, from north to south.

Locality No.	Locality	Year of Installation	No. of nets
1	Richards Bay	1980	14
2	Zinkwazi	1965	8
3	Blythedale Beach	1966	5
4	Tinley Manor	1973	6
5	Salt Rock	1964	11
6	Thompsons Bay	1970	5
7	Ballito	1967	8
8	Westbrooke	1965	6
9	Tongaat	1969	3
10	La Mercy	1980	3
11	Umdloti	1968	6
12	Umhlanga	1964	16
13	Durban	1952	63
14	Anstey's Beach	1952	3
15	Brighton Beach	1952	3
16	North Amanzimtoti	1964	14
17	South Amanzimtoti	1964	14
18	Warner Beach	1964	8
19	Winklespruit	1964	6
20	Karridene	1964	6
21	Umgababa	1970	8
22	Scottburgh	1964	12
23	Park Rynie	1970	8
24	Ifafa	1969	6
25	Mtwalumi	1968	8
26	Hibberdene	1966	5
27	Umzumbe	1968	4
28	Banana Beach	1968	5
29	Sunwich Port	1970	7
30	Southport	1968	4
31	Umtentweni	1967	5
32	St Michaels On Sea	1964	6
33	Uvongo	1964	6
34	Margate	1964	14
35	Ramsgate	1964	10
36	South Broom	1964	6
37	Sysu	1964	6
38	Marina Beach	1964	2
39	San Lameer	1978	8
40	Trafalgar	1965	5
41	Glenmore	1967	4
42	Leisure Bay	1967	6
43	T.O. Strand	1967	6
44	Port Edward	1967	6
45	Mzamba	1981	14

Table 2.2 The netting effort (number of 106m net units) in Natal from 1980 to 1992, measured in January of each year.

Year	Number of net units
1980	346
1981	349
1982	363
1983	369
1984	379
1985	380
1986	400
1987	412
1988	412
1989	416
1990	419
1991	398
1992	419

2.3 RESULTS

2.3.1 Captures

A minimum of 95 humpback dolphins was caught and killed in the shark nets during the period from January 1980 to December 1992, at an average rate of 7,31 (s.d. ± 3,25) per year. Of these, 80 were examined for research purposes, the remaining 15 dolphins were either dumped at sea, lost during retrieval, or not returned for storage. Although sixty-two percent of the catch were males, the annual preponderance of males over females was not significant (t-test t = 1.764; d.f. = 24; p > 0,05). The size of animals ranged from 1,05 to 2,69 m (Fig. 2.1) and males averaged 2,10m (± 0,35) and females 2,06m (± 0,30). The eight captures larger than 2,49 m were all male.

2.3.2 Sightings

A total of 310 sightings of humpback dolphins was reported during the period from January 1984 to December 1992, at an average of 34,4 (± 12,6) per year, or 0,76 (s.e. ± 0,09) per installation per year. Group size, reported on 102 of these occasions, ranged between one and 20 animals, and averaged 5,0 (± 4,8).

2.3.3 Distribution

Seventy-four percent of the catches occurred in the four northern-most netted installations, and 53% of all catches occurred in the Richards Bay nets (Fig. 2.2). Elsewhere the captures were irregularly spaced, and averaged 0,07 (± 0,05) per installation per year. Catches did not correlate significantly with the number of net units per installation (r = 0,365; p > 0,05).

Sightings of humpback dolphins occurred throughout the netted region of Natal (Fig. 2.3). Sightings were neither randomly distributed (Runs test Z = -0,068; p > 0,10) nor correlated significantly with the number of net units per installation (Pearson Product-Moment correlation coefficient r = 0,319; p > 0,10). Annual sightings at Richards Bay were six times the average, and there was a higher frequency (three times the average) in the Umhlanga/Durban/Ansteys Beach areas.

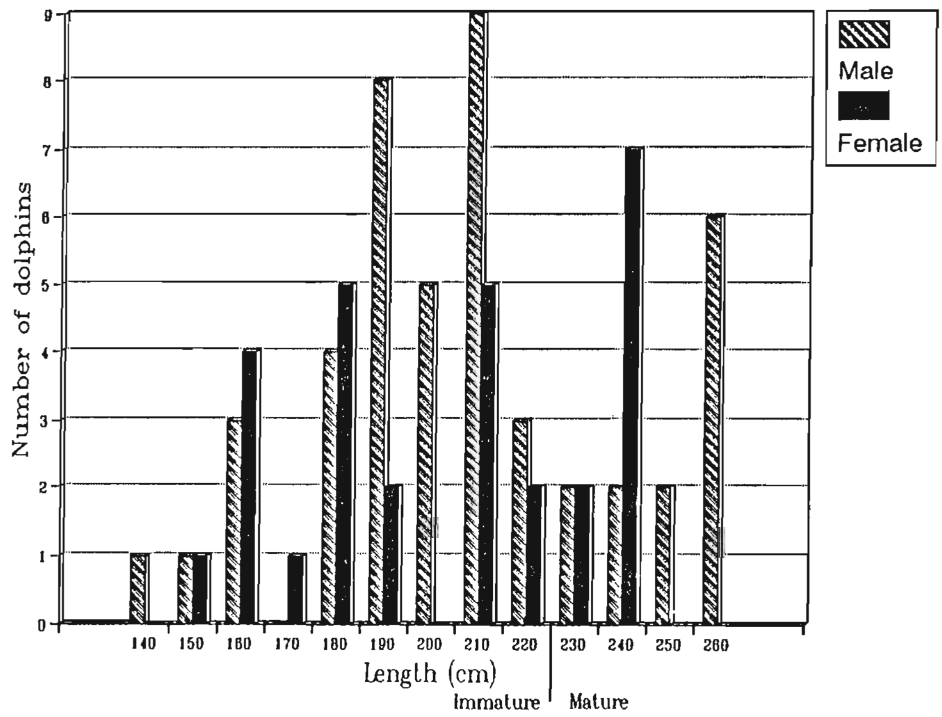

Figure 2.1 Size distribution of male and female humpback dolphins captured in shark nets along the Natal coast between 1980 and 1992, inclusive.

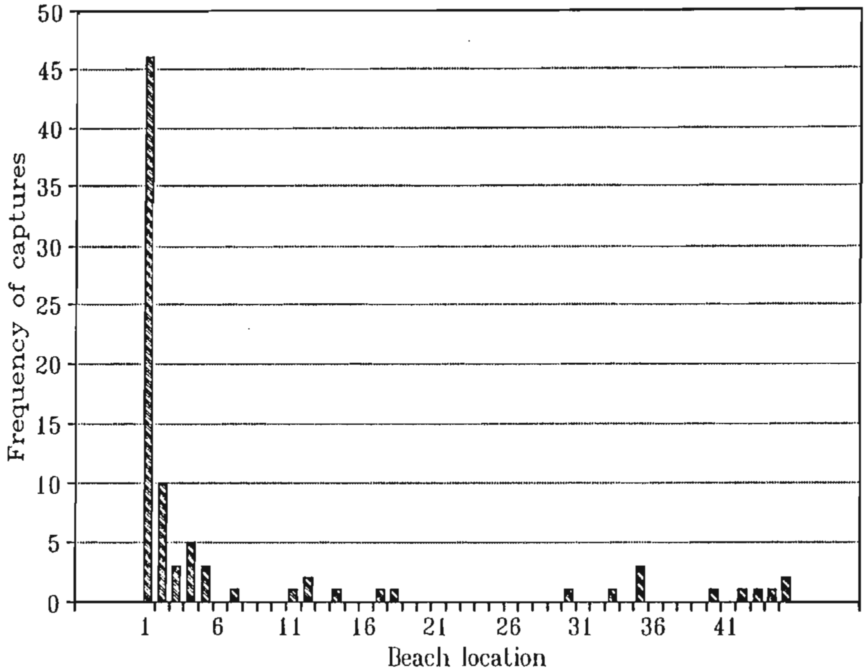

Figure 2.2 Distribution of catches of humpback dolphins along the Natal coast between 1980 and 1992, inclusive. See Table 2.1 for details of installations and nets.

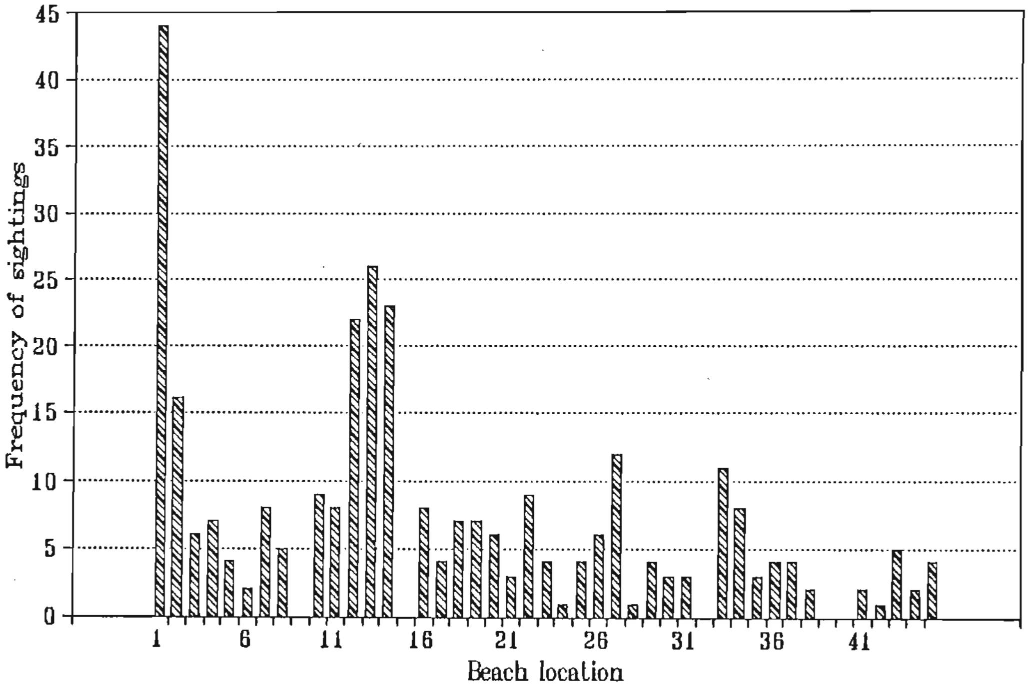

Figure 2.3 Distribution of sightings of humpback dolphins along the Natal coast between 1984 and 1992, inclusive. See Table 2.1 for details of installations and nets.

Sightings and captures of humpback dolphins were relatively frequent in the Richards Bay area, intermediate in the Zinkwasi area, and relatively low elsewhere (figs. 2.2 and 2.3). To determine if there were any discernible differences in the data between areas of high and low capture and sighting frequencies, the data for Richards Bay were compared with those for all other areas combined. Data for the Zinkwasi installation were omitted because frequencies were intermediate between Richards Bay and elsewhere, and thus these data could not be reliably assigned to either category. The average length of captured animals at Richards Bay was 2,08 (s.d. $\pm$ 0,30) m compared with 2,07 ($\pm$ 0,35) m elsewhere. The average group size was 5,1 ($\pm$ 3,3) compared with 5,0 ($\pm$ 5,1) animals elsewhere. A noticeable difference occurred in the sex ratios, however. The 3:1 male to female ratio at Richards Bay differed significantly (Chi^2 = 4,751; d.f. = 1; p < 0,05) from the 1:1 ratio found in other areas. This difference was largely due to a significantly larger proportion (Chi^2 = 3.471; d.f. = 1; p < 0,05) of subadult males (i.e. less than 2,25 m; Cockcroft, pers. comm.) in the Richards Bay area (Fig 2.4). Insufficient data were available to compare seasonal variations in group size between Richards Bay and elsewhere.

2.3.4 Seasonality

Monthly capture records were relatively low (x = 0,49 $\pm$ 0,21 per month per year) and the variation was not significant (Chi^2 = 15,23; d.f. = 11; p > 0,10).

The monthly variation in the number of sightings was significant (Chi^2 = 36.14; d.f. = 11; p < 0,01). A cosine model was fitted to the monthly sighting frequencies using generalized linear models (No. = Exp(a_0 + a_1 cosine (month - 1/2))), and a good fit was obtained (Chi^2 = 7,08; d.f. = 10; p $\approx$ 0,8; p > 0,05)(Fig. 2.5). Thus significantly more groups were seen during the summer months (December to February) than the winter months (June to August).

Although the average group size (Fig. 2.6) appeared bigger during autumn (March and April) than spring (August and September), the monthly variation was not significant (ANOVA F-ratio = 1,118; d.f. = 11; p > 0,10). The correlation between the mean monthly group size and the monthly capture totals (correlation = -0,401; p > 0,10) was not significant.

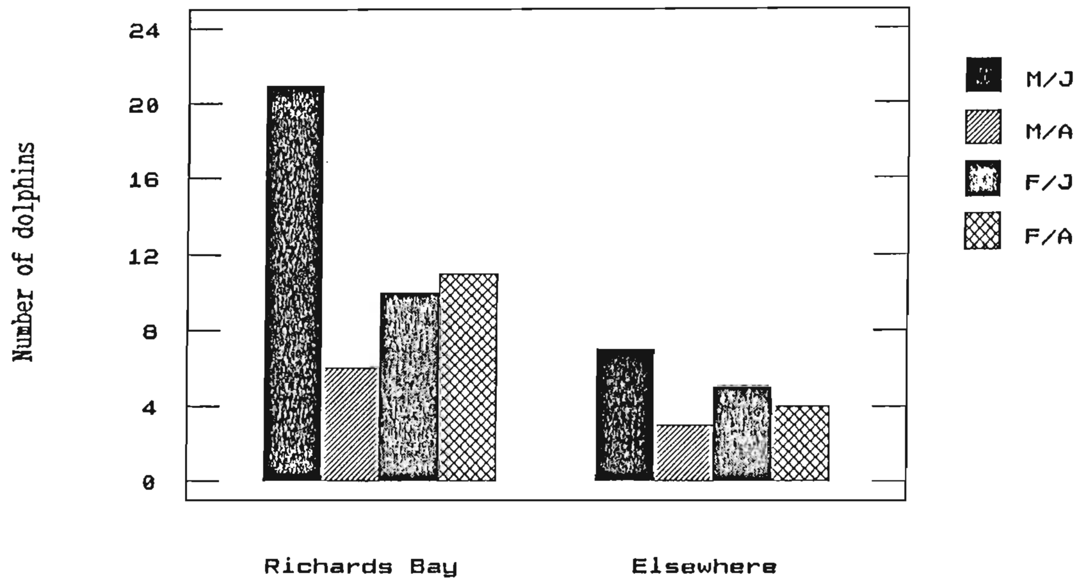

Figure 2.4 Comparison of sex and age classes of net captured humpback dolphins between Richards Bay and all other locations, excluding Zinkwasi. M = male; F = female; J = juvenile; A = adult.

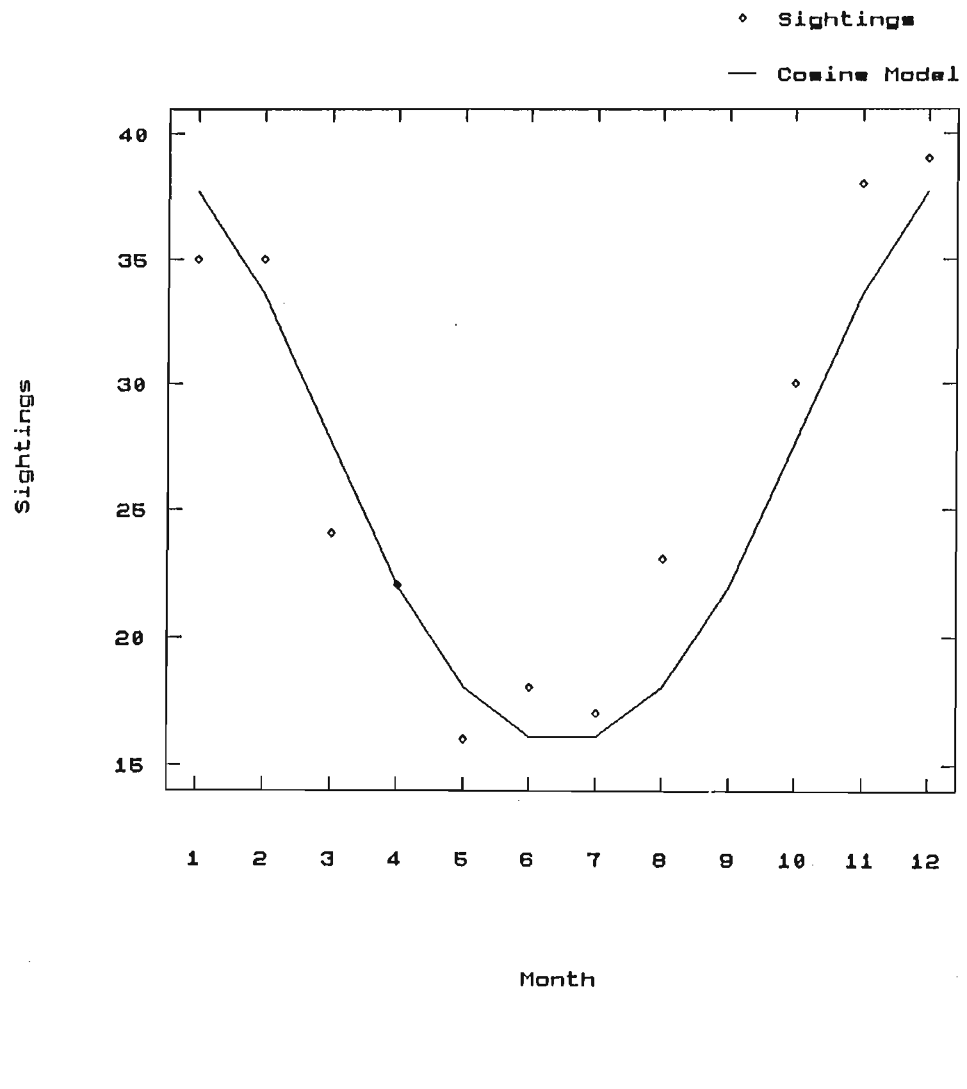

Figure 2.5 Cumulative monthly sightings of humpback dolphins for all locations (1984 to 1992, inclusive) and the fit of a cosine model.

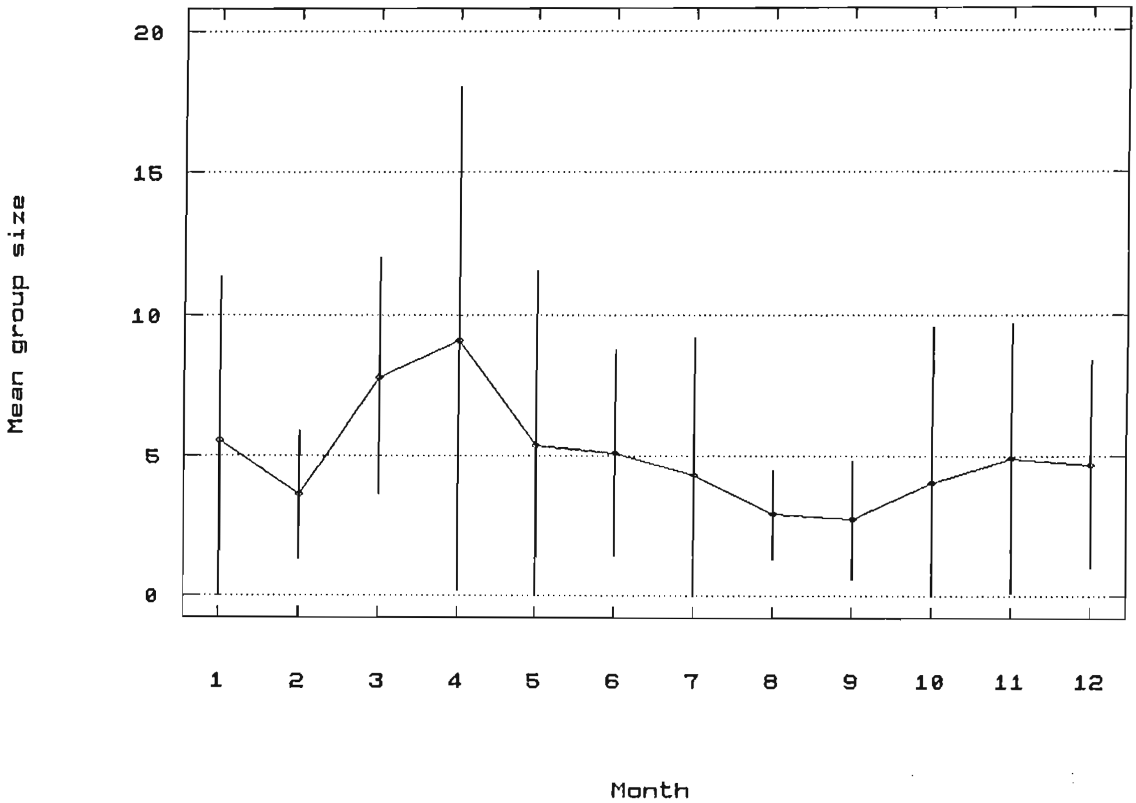

Figure 2.6 Mean monthly group size (+/- standard deviation) of humpback dolphins seen between 1984 and 1992, inclusive.

2.3.5 Annual trends

Although the number of net units increased over the study period (Table 2.2), neither the catch nor the sighting frequency correlated significantly with the netting effort (capture $r = 0{,}305$; $P > 0{,}10$; sighting $r = -0{,}388$; $P > 0{,}10$). Variation in the annual capture frequencies (Fig. 2.7) was not significant ($Chi^2 = 17{,}448$; d.f. = 12; $p > 0{,}10$). The annual sighting frequencies (Fig. 2.7) decreased significantly ($Chi^2 = 36{,}701$; d.f. = 8; $p < 0{,}01$), from an average of 43,7 (± 5,1) sightings per year at all installations for the first three years of recordings (1984-86) to 21,67 (± 4,0) sightings per year for the last three years (1990-92). The decrease was particularly marked at Richards Bay, which declined 84% from an annual average of 9,0 (± 2,6) per year to 1,7 (± 0,6) per year for the same periods, respectively.

2.4 DISCUSSION

The netting effort at the different installations was not uniform, the number of net units per installation varying from two to 63, depending on the public use of the beach. The sighting effort by the meshing staff was also probably biased. This was due to the varying number of nets meshed per boat (i.e. the time spent at sea), the distance of the nets from the launch-site (i.e. the distance covered), and the interest and application of the staff. Seasonal variations in wind strength and direction (Hunter, 1988) would probably have affected the seasonal frequency of sightings (Clarke, 1982). Despite the inherent biases in these data, the non-commercial nature of the Natal Sharks Board and the constancy of their operations argue for a certain consistency in the data. The records are a valuable long-term data set, nine and thirteen years for sightings and captures, respectively, and despite the biases provide a valuable insight into humpback dolphin occurrence and distribution.

The wide size distribution of captured dolphins (1,05 - 2,69 m) indicates that the net captures were not size specific, and indicates that the Natal population is reproductively active. However, the captured population is not necessarily representative of the proportion of size ranges occurring in the natural population, as the nets may selectively

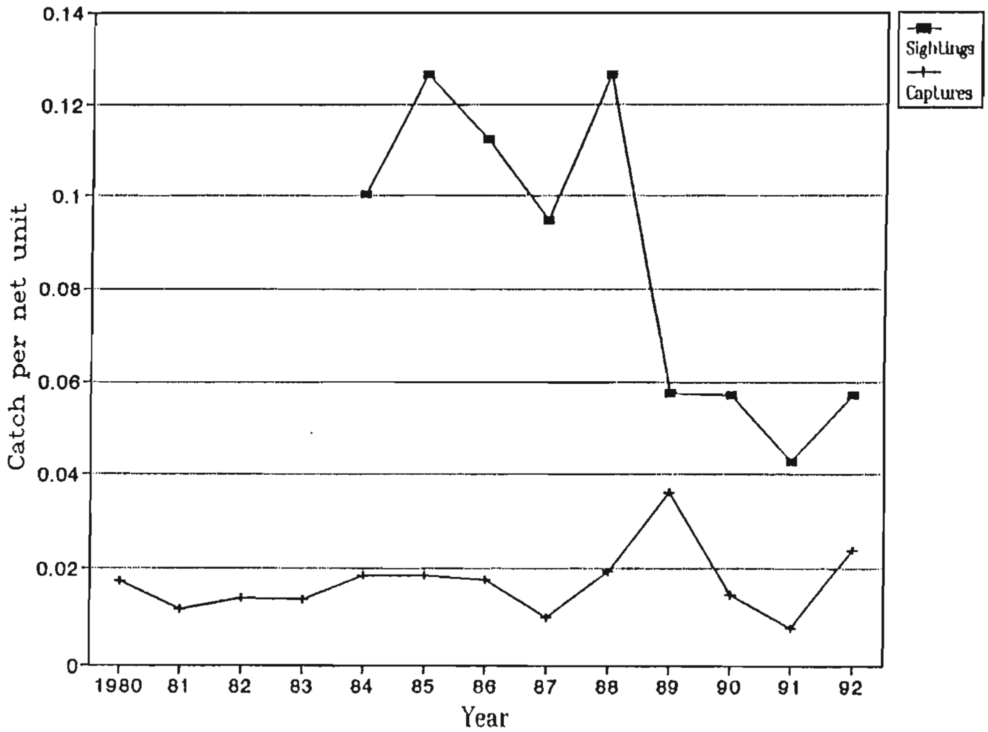

Figure 2.7 Annual catch and sighting rates of humpback dolphins between 1980 and 1992, inclusive, and between 1984 and 1992, inclusive, respectively.

capture either predominantly large or small dolphins. Based on the length of animals captured in the nets, Cockcroft (1990a) suggested that sexual dimorphism was evident in the natural population. The fact that eight males in this study were larger than the largest female (i.e. >2,49m) does not contradict this hypothesis.

The size range of humpback dolphin groups (*viz.* 1 - 20 individuals) and the mean group size (*viz.* .5 animals) was consistent with other studies (Saayman & Tayler, 1979; Ross *et al*, 1994), where reported group size was usually less than 25.

Humpback dolphins were captured and sighted throughout the netted areas of southern and central Natal. Fifty-three percent of the captures, however, occurred at the northern-most net installation (Richards Bay), 49 times the average for all other installations. Sightings in this location were also higher, seven times the average for other installations. The higher frequencies probably indicates a greater density of humpback dolphins in this locality. The low frequencies of captures and sightings in other areas of Natal indicates either a low density of dolphins or an infrequent occurrence of the dolphins.

The nets at Richards Bay were installed in 1980, unlike the nets in most other areas which were installed in the 1960's and 1970's (Cliff, Dudley & Davis, 1988). If the nets were responsible for depleting the dolphin population, this could explain the relatively higher density of dolphins at Richards Bay, where the population levels have not [yet] dropped to levels apparent elsewhere, where nets have been in longer use. There has been a decrease in sighting rates at Richards Bay over the last decade, which are more marked than elsewhere, although no decrease in captures has yet been recorded in this locality. Alternatively, the higher density of humpback dolphins at Richards Bay could just be a reflection of a more favourable habitat in this area.

To determine whether the social structure of the Richards Bay population was different from elsewhere, the data from this locality were compared to those from all other locations. Zinkwasi was omitted because the capture and sighting frequencies were intermediate between those recorded for Richards Bay and elsewhere could thus not be reliably assigned to either category. The male:female sex ratio of captured animals at

Richards Bay was 3:1, in comparison with an equal proportion elsewhere. The higher frequency of male captures at Richards Bay may reflect the sex ratio in this area, but could also be due to behavioural differences between the sexes. The humpback dolphin could be similar to other delphinid species, for example the bottlenose dolphin, where differences occur in the patterns of habitat usage and group affiliation between the sexes. Scott, Irvine & Wells (1990) found that female bottlenose dolphins in the Sarasota Bay, Florida, "community", occur closer inshore, have high group affinities, and tend to have smaller ranges than the male dolphins. The unequal sex ratio in the capture sample from Richards Bay was largely due to a predominance of subadult males (i.e. $<$ 2,25 m in length). There is insufficient evidence to suggest a reason for such a ratio in the Richards Bay population. However, dispersal strategies of many mammal populations are often based on the movements of particular age or sex classes (Snyder, 1976). The unequal ratio of subadult males to females in this area may therefore reflect a particular dispersal strategy. Although the sex ratios differed, there were no significant differences in the average length of captured animals or the average group size between Richards Bay and other netted areas.

Sighting frequencies varied seasonally, with more sightings occurring during the austral summer. As sighting conditions (for example Clarke, 1982) during winter are more favourable (i.e. the sea is calmer and turbidity from river run-off is less) in Natal than during summer, the higher rate of summer sightings suggests that this increase is not an artifact.

The summer increase in sightings may partly be due to more sightings of the same group (i.e. a higher degree of group movement between netted installations), although the twofold increase in the daily number of sightings probably indicates that more groups were "available" for sighting. Alternatively, the increased summer sighting rate could be due to a summer increase in group size, assuming that the probability of sighting correlates directly with group size (and therefore visibility to observers). The apparent trend in group size, although not significant, did not support this. In Plettenberg Bay in the Eastern Cape humpback dolphin group size tended to increase during winter (Saayman & Tayler, 1979). If parallels can be drawn between these two areas, both on the south east coast of Africa, it would suggest that this explanation for a seasonal variation in group size is unlikely.

Even though the search area of the meshing officers is restricted, it is unlikely that the seasonal increase in sightings during the summer would be caused by local movements, as net installations are located, on average, only 5,6 km apart, over a total distance of approximately 240 km. Consequently, the seasonal variation is sighting rates is considered to be due either to seasonal shifts between nearshore and offshore positions, or to extensive (>100 km) seasonal movements of at least some humpback dolphins along the coast. Although Maigret (1981) had not identified any individuals, he reported summer movements of humpback dolphins (*Sousa teuszii*) in West Africa, where the dolphins apparently moved from Senegal to Mauritania.

Saayman & Tayler (1979) found that the humpback dolphin was strictly coastal, usually remaining within 250 metres of the shore, and they did not note (and therefore not examine) seasonal movements between inshore and further offshore positions. Again, if parallels can be drawn between the two populations, this would argue against the inshore/offshore explanation for seasonal variations in sighting frequencies in Natal. The restricted area of operation of the net meshers implies, however, that even a relatively small inshore/offshore movement could account for the seasonal variations in sighting frequencies.

Based on the repeated resightings of three individuals, Saayman and Tayler (1979) suggested that the humpback dolphin was resident throughout the year in Plettenberg Bay in the Eastern Cape. As these researchers were limited to Plettenberg Bay in their study they were, however, unable to determine the extent of the movements of the dolphin.

Although there was no apparent parallel seasonality in the capture data, the sample size was small and any conclusions would therefore be tenuous. If accurate, the capture data may contradict the apparent seasonality of the sightings. Alternatively, they may indicate that the dolphins exhibit a behavioural difference between seasons. For example, although fewer dolphins may be available for capture during winter, their behaviour may make them more prone to capture.

Annual sighting frequencies off three adjacent installations, at Ansteys, Durban and Umhlanga beaches, were relatively high. There were more nets than average in the Umhlanga and Durban areas, and thus the sighting and capture effort (time spent "meshing" the nets) was great, possibly explaining the increased level of sightings in these locations. In contradiction, however, there were no recorded captures. The fraction of captures / sightings at Richards Bay (0,72) was considerably higher than the average for all other netted beaches in Natal (0,11). These data suggest that capture rates were not only related to the occurrence of dolphins, as proposed by Cockcroft & Krohn (in press), but may also have been influenced by physical or behavioural factors.

Examining dolphin captures during the period 1980 - 1988, Cockcroft (1990a) expressed concern about the status of the humpback dolphin in Natal. In addition to mortality in the shark nets, the organochlorine levels in humpback dolphins in Natal were higher than any other marine mammal off South Africa (Connell, 1988; Cockcroft, 1989), with potentially negative effects on infant survival and reproductive rates (Subramanian, Tanabe, Tatsukawa, Saito & Miyazaki, 1987; Addison, 1989; Cockcroft, De Kock, Lord & Ross, 1989). The Natal Sharks Board sightings of humpback dolphins have declined 55% from the average of the first three years of recording (1984-86) to the most recent three (1990-92). The decline was particularly marked at Richards Bay, where the sightings decreased by 84%. No significant parallel trend in captures was, however, found. If the sighting data accurately represent a trend (rather than a temporary fluctuation) in the population, these data probably indicate that the humpback dolphin population in Natal is decreasing.

CHAPTER 3

SOME ASPECTS OF THE ECOLOGY OF THE HUMPBACK DOLPHIN ALONG THE NATAL COAST.

3.1 INTRODUCTION

The benefits offered by various habitats, including protection from the elements and predation, food availability and lack of competition, cluster animals into a mosaic of densities. For example, relatively high densities of bottlenose dolphins *Tursiops truncatus* have been reported to occur in the vicinity of estuary mouths (Dos Santos & Lacerda, 1987; Hansen, 1990; Ballance, 1992) and over areas of sea grass (Hansen, 1990; Scott, Irvine & Wells, 1990). This distribution is partly related, presumably, to food availability. Nursery schools remain in shallow, enclosed bays during spring when the newborn calves are most vulnerable to shark predation (Scott *et al.*, 1990).

Benefits may not be found in one particular habitat, and movements may occur between different areas, giving rise to temporal changes in densities. Spinner dolphins *Stenella longirostris* feed in deep water during the night and move into shallow, sandy coves or lagoons during the day (Norris & Dohl, 1980). The humpback whale *Megaptera novaeangliae* moves annually between the nutrient-rich arctic and antarctic waters to the warmer tropics where it breeds (Katona & Whitehead, 1981; Darling, Gibson & Silber, 1983).

Capture and sighting records of the Natal Sharks Board and the Port Elizabeth Museum (Chapter 2) indicate that the humpback dolphin occurrs throughout Natal. The frequencies of captures and sightings varied, however, with locality, low frequencies being recorded for most of Natal, and a higher frequency at Richards Bay. In addition, the sighting records indicate a significant seasonal change in frequency. This chapter further investigates the occurrence of the humpback dolphin along the Natal coast and attempts to correlate distribution patterns with biological, behaviourial, environmental and physical parameters.

3.2 MATERIALS & METHODS

Searches for humpback dolphins took place parallel to the coastline at a distance of approximately 200 metres from the surfline where dolphins were most likely to be found. The transect width was approximately 200 m on either side of the boat.

Searches took place on good weather days (Beaufort scale 0-3) in a 4,3 metre inflatable craft driven at a constant speed and powered by a 30 horsepower outboard engine. Ten localities in Natal (Fig. 3.1) were searched repeatedly. Search distances ranged between five and 42 km, but averaged 18 km. If humpback dolphins were found, the search was discontinued and the time noted. When all required photographs were taken, or when dolphin behaviour prevented further photography, the search was resumed and the time again noted.

A group of dolphins is here defined as those animals collectively moving separately from and apparently independently of other individuals or groups. Underwater echolocatory sounds may travel up to 300 metres (reviewed in Gaskin, 1982) and other sounds (leaping, tail slapping, jaw clapping) may travel for one or more kilometres before significant attenuation (Gaskin, 1982; Wursig, 1986). Thus single dolphins or groups were only considered separate if found a minimum distance of one kilometre apart.

Dolphins were counted (a subjective estimate based on different positions at surfacing, differing sizes, fin markings, the size of the hump, colouration, and other identifying features), photographed, and the geographical position noted using a "Decca Navigator". The activity (socially active, feeding, resting or progression - described in Chapter one) of the dolphins was recorded, where possible. Progression was noted only if the movement persisted for two or more kilometres. The water depth (shot line length) and

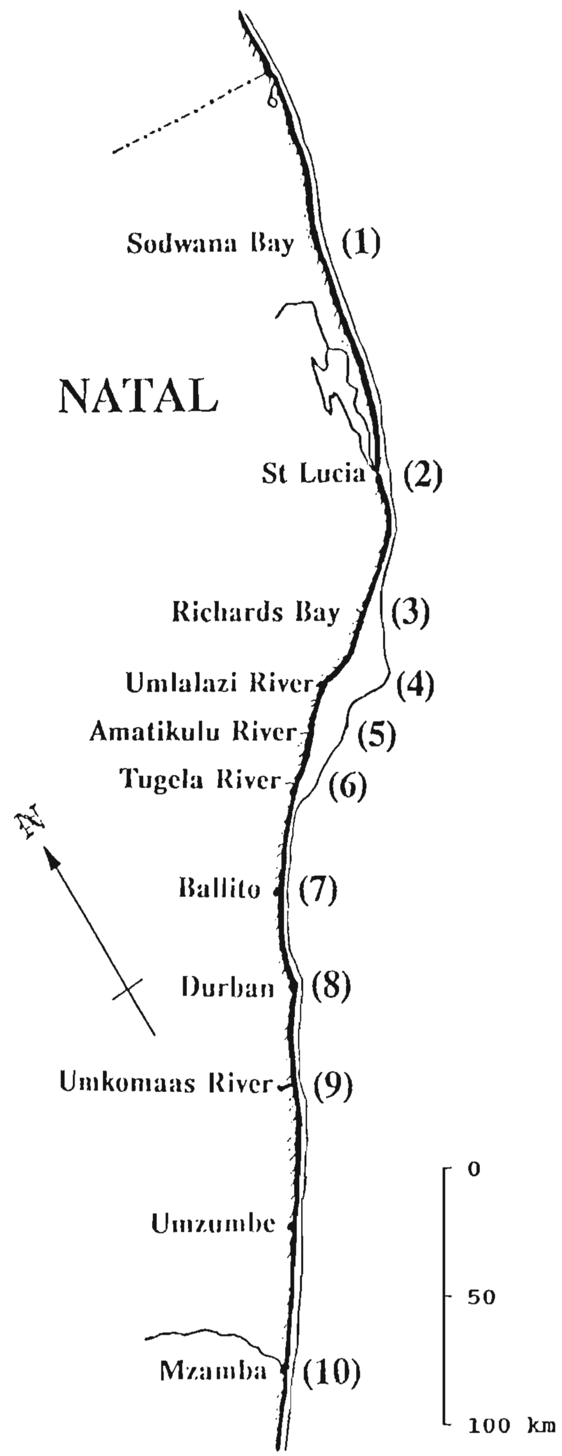

Figure 3.1 Location of the ten search areas along the Natal coast, South Africa. The position of the 15 m isobath is shown.

water clarity (Secchi-disc depth) were measured in the immediate vicinity (within ten metres) of the dolphins. Bottlenose dolphins, if sighted, were also counted, and checked for the presence of humpback dolphins amongst them.

The Natal Sharks Board reported sightings of humpback dolphins to me on four occasions. The data from two successful follow-up launches at Ballito and Warner Beach were included only in the behavioural analysis.

3.3 RESULTS

A total of 285 hours (excluding observation time) was spent searching for humpback dolphins. Most (58,5%) of Natal's 550 km of coast was searched at least once. Repeated searches (between two and 41 times) were undertaken along various lengths of coastline, from several launch sites (Fig. 3.1).

Group size ranged from one to 18 dolphins (Fig. 3.2), with a mean ($\pm$ standard deviation) of 6,7 $\pm$ 5,3. Approximately 20% of sightings were of lone animals. Humpback dolphins were sighted on 56 of 136 searches (41%) between March 1991 and August 1992 allowing for a total observation time of 86,7 hrs. Sixty-one separate groups or lone animals were seen. The mean maximum water depth in which humpback dolphins were observed was 15,7 $\pm$ 5,4 m. On two occasions (17/8/91; 18/4/92) dolphin groups were followed to a distance of approximately six kilometres and eight kilometres offshore. The depth in each case did not exceed 23 m and 18 m respectively. Bottlenose dolphins were found on 52 (38%) searches. No lone bottlenose dolphins were seen: The bottlenose dolphin group size ranged from two to 150 animals, and averaged 25,7 $\pm$ 22,2.

Mean group size varied significantly (ANOVA F Ratio = 3,426; d.f. = 9; $p < 0,01$) between search areas (Fig. 3.3). The sighting data were therefore analyzed as the sighting rate of dolphins per hour in each search area. The sighting rate of humpback dolphins (Fig 3.4 A) correlated positively with the average distance between the shore and the 15m isobath (i.e. width of the inshore continental shelf - taken from South African Navy

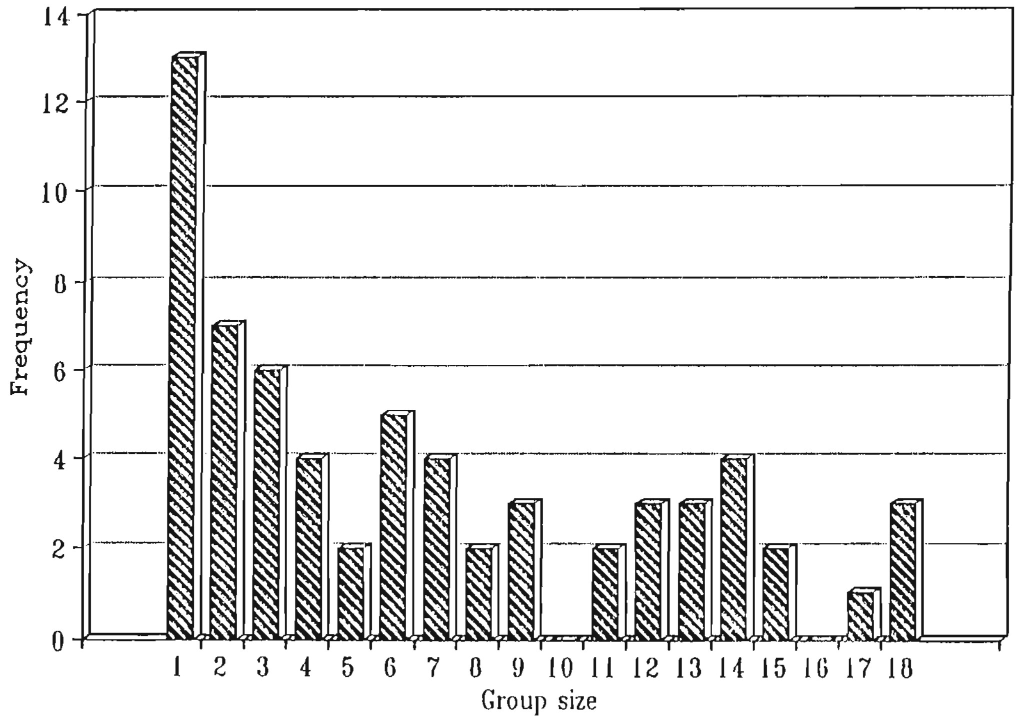

Figure 3.2 Frequency of humpback dolphin group size observed in all search areas.

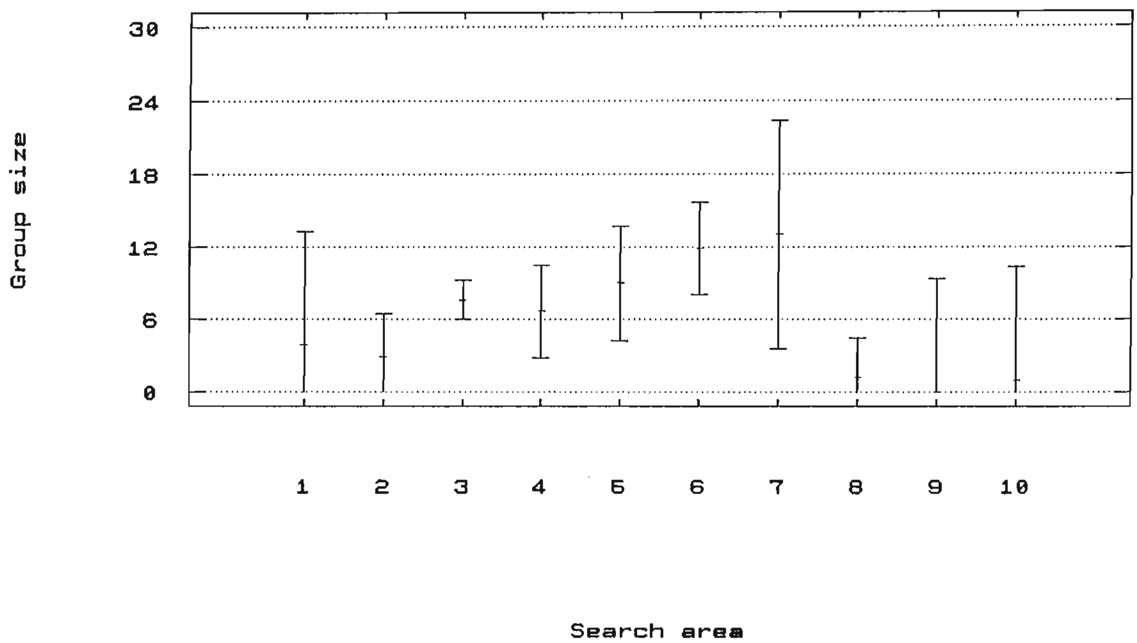

Figure 3.3 Mean (+/- standard deviation) group size of humpback dolphins in each of the ten search areas.

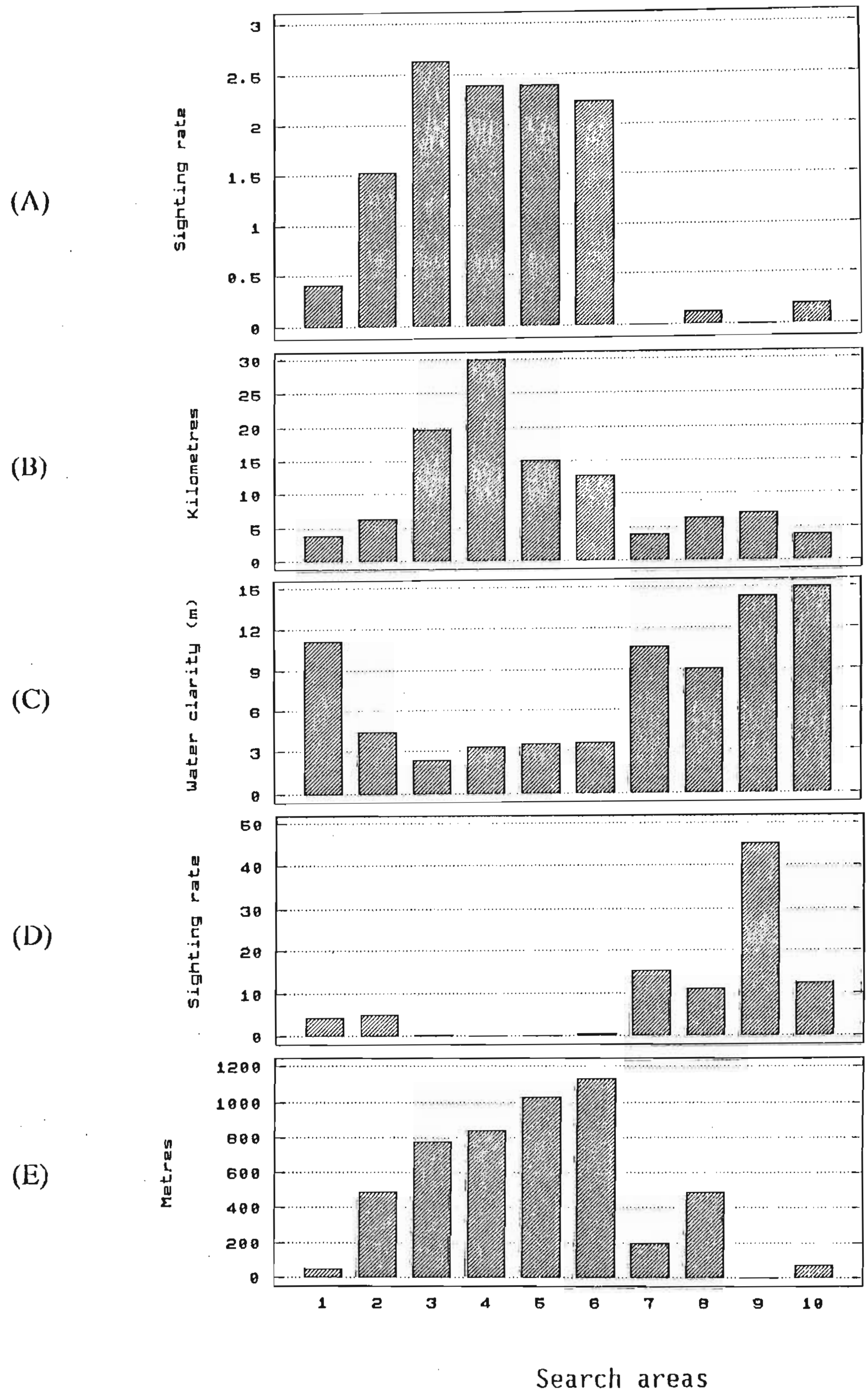

Figure 3.4 Physical and biological parameters measured in each of the ten search areas: (A) Sighting rate (individuals per hour) of humpback dolphins; (B) Average width of the inshore area extending to the 15m isobath; (C) Water clarity (secchi-disc depth) in the immediate vicinity of the dolphins; (D) Sighting rate (individuals per hour) of bottlenose dolphins; and (E) Average distance offshore that humpback dolphins were followed.

charts)(Fig. 3.4 B)(Pearson Product-Moment correlation coefficient $r = 0{,}793$; $p < 0{,}05$), and negatively with the water clarity (Fig. 3.4 C)($r = -0{,}916$; $p < 0{,}01$) and sighting rate of bottlenose dolphins (Fig. 3.4 D)($r = -0{,}910$; $p < 0{,}01$). The average distance offshore that the dolphins were followed in each area (Fig. 3.4 E) correlated loosely with the average width of the inshore continental shelf ($r = 0{,}665$; $p = 0{,}07$).

A total of 96 humpback dolphins were identified from slides taken during the study. Eighty-four (87,5%) were identified in the northern Tugela Bank region, seven (7,3%) in the Durban area, and the remaining five (5,2%) elsewhere in Natal. Humpback dolphins were seen in all months that photo-identification searches took place in the northern Tugela Bank region. Searches did not take place in February and December.

Within the northern Tugela Bank region, humpback dolphins were found most often within a distance of four kilometres from an open river system (Fig. 3.5). The relative sighting frequencies at different distances from a river system were used to estimate the expected relative frequencies of captures in net installations based on their distance from the rivers of the northern Tugela Bank (Fig. 3.6). There was no significant difference between expected and observed relative frequencies ($Chi^2 = 1{,}12 \times 10^{-3}$; d.f. = 1; $p = 0{,}97$; $p >> 0{,}10$).

Most (59%) dolphins photographed and identified on more than one occasion were resighted only in the vicinity of their first sighting (Table 3.1). The remainder were photographed and identified in either one (27%) or two (14%) of the other areas searched repeatedly. The maximum distances between re-sightings on the northern Tugela Bank ranged from 17 to 70 km. One animal was identified off Durban on 13 June 1991 and was re-sighted on the 25 June 1992 off the Umlalazi River, 120 km away. Progression was seen on four occasions (seven percent of all sightings). It was seen only once on the northern Tugela Bank, where a group of dolphins was seen to move between two river systems. The other three occasions when progression was seen occurred outside the northern Tugela Bank. A description of these serves to illustrate progression:

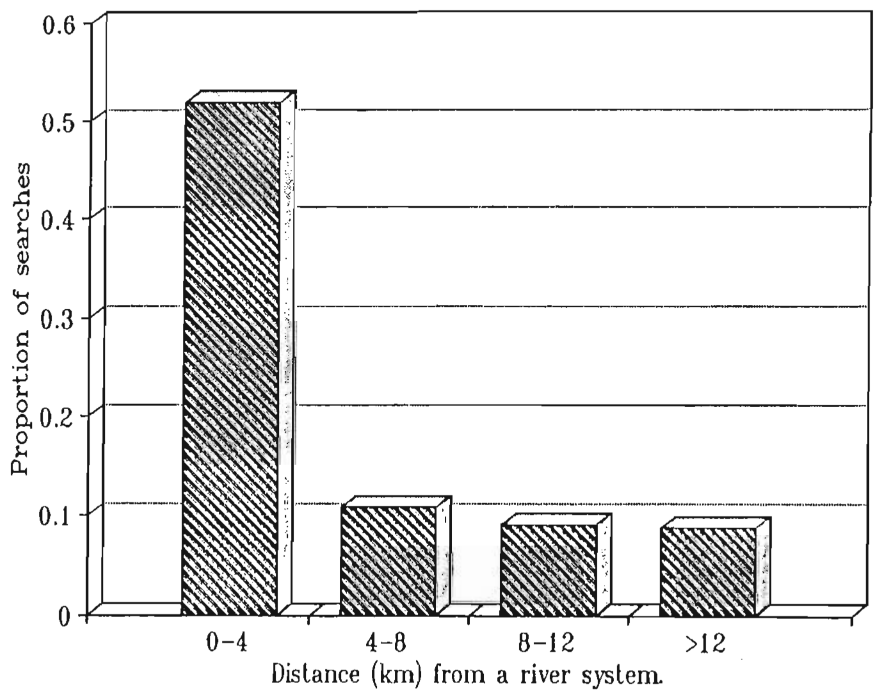

Figure 3.5 Proportion of searches finding humpback dolphins in zones categorized by their distance from any of the river systems on the northern Tugela Bank.

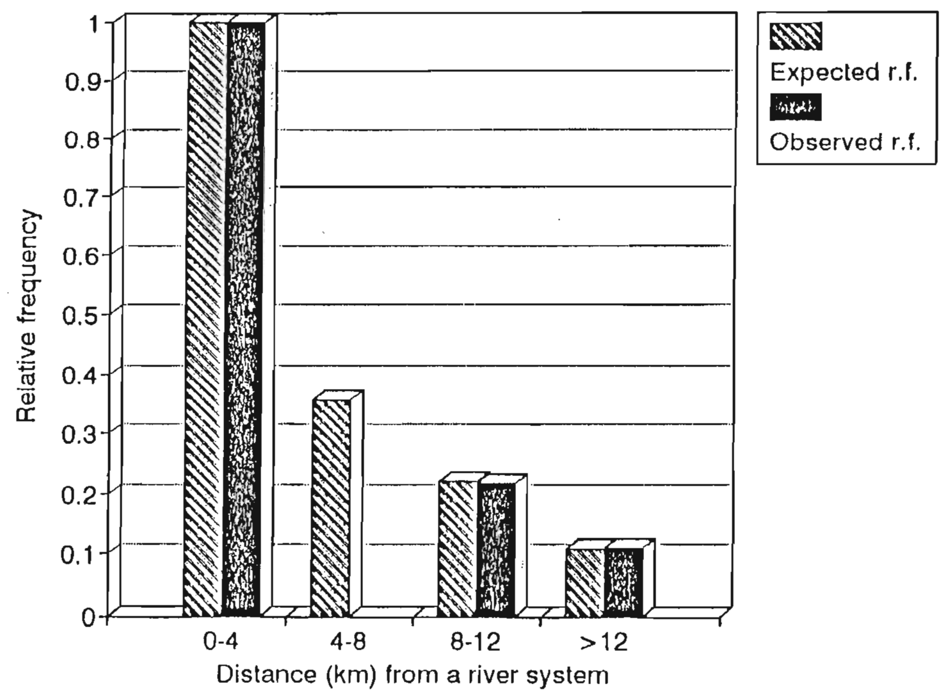

Figure 3.6 Expected and observed relative frequency (r.f.) of captures in nets positioned at different distances from the closest river system on the northern Tugela Bank. The observed capture frequencies were relative to those recorded at Richards Bay (assigned a frequency of 1) where the nets are located in the 0-4km zone. There is no net installation located between 4 and 8 km from a river system. The expected capture frequencies were derived from the proportion of searches (Fig. 3.5) finding humpback dolphins in each zone, plus the proportion of searches finding dolphins in zones further from the river system (i.e. including those dolphins assumed to have passed through that zone).

Table 3.1 The number of re-sighted dolphins seen in only one search area compared to the number seen in two or three different search areas.

No. of search areas	Probable females	Others	Total No. of dolphins
1	8	21	29
2	2	11	13
3	-	7	7

20/3/91: A sighting at Ballito (search area seven) followed a NSB report of dolphins in this area. The group of approximately 13 animals moved persistently along the shore at a speed of approximately 4,2 km/hr, and by the end of the observation period had covered a distance of approximately eighteen kilometres.

4/10/91: Another sighting due to a NSB report at Warner Beach, just south of Durban (search area eight) was of a group of five dolphins which moved consistently along the shore for 23 km at a speed of approximately 2,8 km/hr.

9/12/91: At Mzamba (search area ten) a lone dolphin was seen moving at high speed (approximately ten km/hr) and followed for approximately six km.

While feeding accounted for approximately 57% of behaviours observed both along and away from the northern Tugela Bank (Fig. 3.7), the other behaviours (resting, progression and socially active - described in Chapter 1) varied between these two regions. Progression predominated over both resting and socially active behaviour away from the northern Tugela Bank, whilst on this bank resting and social behaviours were more commonly seen. On eight occasions humpback dolphins were seen in close proximity (probably within visual and/or aural range as defined above) to bottlenose dolphins. On all occasions interactions were apparently amicable. A single identified dolphin re-sighted in the Durban area was seen feeding and moving with bottlenose dolphin schools on five of six occasions. On the last sighting, however, this humpback dolphin was in the company of another humpback dolphin, and both were observed feeding and interacting socially.

Fifteen individuals were considered to be females because of consistent close association with calves. On no occasion was a female and calf pair found alone. Females in the Richards Bay area (the most frequently searched area) were re-sighted significantly more often than other dolphins (t-test; $t = 2.829$; d.f. $= 41$; $p < 0,01$)(Table 3.2). The proportion of resident to mobile (i.e. resighted in more than one search area - Table 3.1) female dolphins was greater than that of "other" dolphins, and had a significance level of

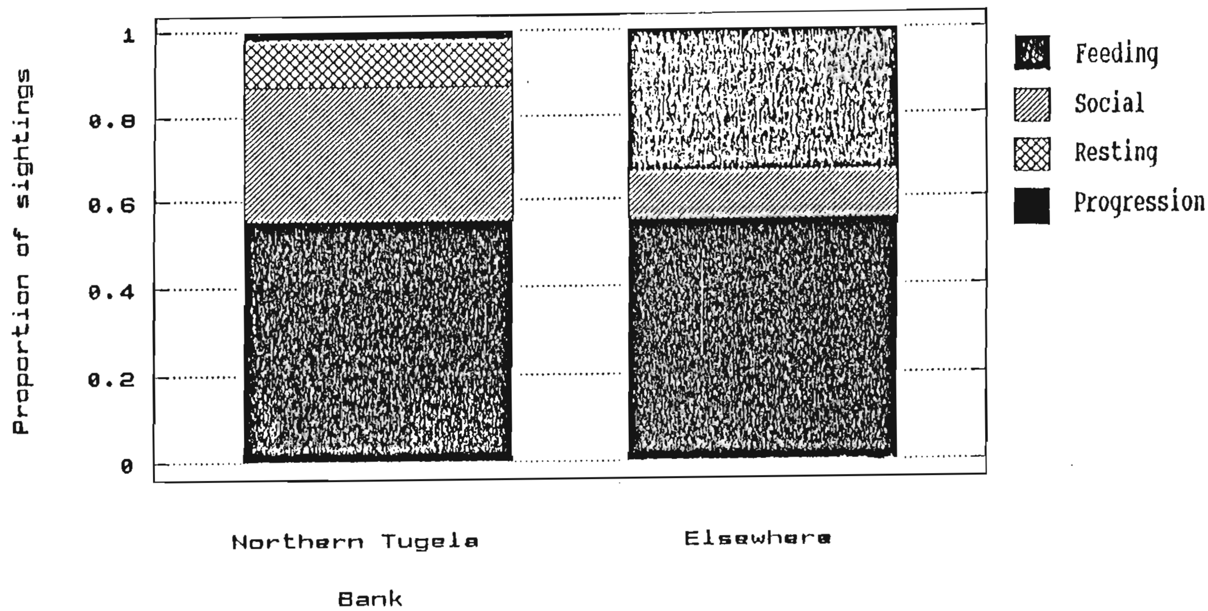

Figure 3.7 Comparison of the predominant behaviours at each sighting between the northern Tugela Bank and other search areas.

Table 3.2 Re-sighting frequencies (number of months seen) of adult female and other humpback dolphins in the Richards Bay search area.

	Number of months seen						
	1	2	3	4	5	6	7
Probable females	2	1	1	2	2	-	1
Others	18	6	4	4	2	-	-
All dolphins	20	7	5	6	4	-	1

between 0,06 and 0,07 (proportion test; z = 1.50). Although this is higher than the generally accepted significance level of p = 0,05, it is still considered to be significant because the "other" category probably included unidentified female dolphins.

3.4 DISCUSSION

This study did not examine critically the distribution of the dolphin relative to the depth of water, as the over-riding need was to find and identify dolphins for the population estimates (Chapter 4). Hence the searches proceeded parallel and close to the shore. However, during observation of dolphin groups, the water depth was measured regularly. On many occasions the group being observed either did not move far offshore or would turn back after a period of time, and on no occasion did the followed groups move into water of depth greater than 26 m. The mean maximum water depth in which the dolphins were followed was 16m. The average distance that dolphins moved offshore during observation was greater where the 15m isobath (i.e. shallow water zone) extended further offshore.. This evidence suggests that the distribution of the dolphin was indeed limited by depth. On the northern Tugela Bank region, where the shallow water zone extends further offshore, the sighting rate of the dolphins may therefore be negatively biased, given that all searches were close to the shore.

Despite any such possible bias, the sighting rate of humpback dolphins in Natal was found to be markedly higher along this northern Tugela Bank, which extends from the St Lucia estuary to the Tugela River mouth (approximately 140km). The relatively high frequency of captures and sightings recorded in the Richards Bay area by the Natal Sharks Board (Chapter two) are consistent with this.

Relatively low sighting rates of humpback dolphins north and south of the northern Tugela Bank were found in this study. The low rates indicate either that there are a low number of dolphins occurring in these areas, and/or the dolphins occur only infrequently in these areas. It was a strong subjective impression that the majority of dolphins seen outside the northern Tugela Bank were transient animals not resident in the particular search area.

Three groups, for example, were observed to move persistently for minimum distances of six, 18 and 23 km, respectively, along the coast (in contrast progression was only seen once in 51 sightings along the northern Tugela Bank). One animal, originally identified off Durban, was later resighted 120km away on the northern Tugela Bank. The only exception to the impression of transient animals outside the northern Tugela Bank was due to a single humpback dolphin being resighted six times in the Durban area.

Physical features correlating significantly with the high sighting rate of dolphins in north central Natal were a low water clarity and a wide inshore continental shelf (the northern Tugela Bank). These two factors are possibly inter-connected: high, year round turbidities (Van der Elst, 1975; Schumann, 1988a; Cockcroft, 1990a) occur along the northern Tugela Bank as the turbulent, shallow seas maintain the sediment in suspension (Flemming & Hay, 1988). Additionally, the two largest river systems in Natal, the Tugela River and the St. Lucia estuary (Begg, 1978), both with high silt levels (McClurg, 1988; Schumann, 1988b), occur in this region.

Cockeron (1990) reported that the humpback dolphin at Moreton Bay, Australia, was more likely to be seen in "the western side of the bay, where waters remain fairly shallow for many kilometres offshore". Although water clarity was not examined in that study, the author did comment that relatively high densities of bottlenose dolphins and relatively low densities of humpback dolphins were found where the water was clearest. These comments are consistent with the findings in this study. In contrast, however, Saayman & Tayler (1979) found the humpback dolphin to be resident in the clear waters (with a water clarity of up to 24m) of Plettenberg Bay. This suggests that water clarity may influence the relative density of the dolphins, but does not limit their distribution.

Barros & Cockcroft (1991) and Ross *et al* (1994) reported that the humpback dolphin feeds on demersal and reef associated prey, in addition to littoral and estuarine associated species. The wide and shallow inshore shelf may thus increase the available habitat for humpback dolphins. The restricted visual sense in turbid waters may also give a predatory advantage to the dolphins, which can use echolocatory sounds in hunting.

There was also a significant negative correlation with the sighting rate of bottlenose dolphins. The reciprocal relative "densities" of humpback and bottlenose dolphins along the Natal coast may indicate competition for resources. There is some overlap of prey species (Barros & Cockcroft, 1991; Cockcroft & Ross, 1990), and Saayman & Taylor (1979) reported some incidents of aggression between the two species. Cockeron (1990) reported that the bottlenose dolphin, although not apparently aggressive, appeared to be dominant over the humpback dolphin in Moreton Bay. All interactions between the two species observed during this study were apparently amicable, even playful, and one lone individual was seen on five occasions swimming with a bottlenose dolphin school. The reciprocal sighting rates of the two species in Natal is thus thought more likely to be due to different habitat preferences. The bottlenose dolphin's preference for clear water has been reported (Ross, 1977; Zbinden, Pilleri, Kraus & Bernath, 1977; Pilleri & Pilleri, 1979; Richards, 1985),a suggested reason being to avoid potential shark-attack (Richards, 1985). As the environmental parameters in this study were merely correlated with the dolphin sighting rate, it was not possible to state which, if any, most influenced their occurrence.

Group size has been suggested to vary according to, amongst others, predation pressure and/or food availability (Norris & Dohl, 1980). Examining net caught humpback dolphins, Cockcroft (1990b) found that 28% of these had scars consistent with shark attack, implying a considerable population pressure due to shark predation. Given that there were 43 shark net installations in southern Natal, averaging 5,3 km apart, predation pressure from shark attack in this region is presumably less than along the northern Tugela Bank, where two installations occur along approximately 140km (70 km apart). The larger group size along the northern Tugela Bank may be due in part, therefore, to increased predation on dolphins by sharks.

Along the northern Tugela Bank the sighting rate within each search area was not found to be uniform. Proximity to the five large river systems in this region markedly influenced the sighting rates, groups being most frequently found within a four kilometre radius of river outlets. Expected relative capture frequencies estimated from the relative sighting frequencies at different distances from river systems along the northern Tugela Bank correlated very closely with "observed" capture frequencies in net installations. This offers further support to the association of humpback dolphins with river systems. The association was not unexpected, given several, albeit anecdotal, reports on humpback dolphins frequenting estuaries and river mouths (for example: Pilleri & Gihr, 1972; Zbinden *et al.*, 1977; Pilleri & Pilleri, 1979; Roberts, Khan & Knuckley, 1983). The distribution of the coastal form of the bottlenose dolphin (*Tursiops truncatus*) is also influenced in some areas by the proximity to estuaries (Dos Santos & Lacerda, 1987; Hansen, 1990; Ballance, 1992). The high productivity associated with estuaries is well documented (Branch & Branch, 1985) and presumably the association of these dolphins with river systems is primarily for food (Scott *et al*, 1990).

The majority of all individuals seen more than once were resighted, during the course of the 17 month study, only in the vicinity of their first sighting. As the time spent searching in each search area was unequal, the level of movement between search areas cannot be determined. Despite this, the evidence suggests that humpback dolphins show at least some fidelity to a particular area. Saayman & Tayler (1979) suggested, based on the frequent resighting of three identified individuals over their three year study in the Eastern Cape, that the humpback dolphin utilized a limited and familiar home range. They could not give the extent of this range.

Insufficient data on the movement patterns and behaviour of the dolphins was obtained in this study to describe adequately the home range, defined loosely (Burt, 1943) as "that area around the established home which is traversed by the animal in its normal activities of food gathering, mating and caring for the young. It excludes occasional sallies outside the area". Nevertheless, it can be inferred from the above data that the home range could possibly be the limited coastal area possibly surrounding each river system, and the movements between ranges form infrequent "wanderings" or "exploratory sallies". Alternatively, the home range could be the entire northern Tugela Bank, with the estuaries or river mouths forming focal points, or "core areas" (Jewell, 1966) of such a range.

Identified pregnant and lactating dolphins (assumed to be thus because of their close association with a young calf during some stage in the study), were resighted more often than other dolphins. Mother/calf pairs would presumably be more visible to observers than single dolphins, thus potentially biasing resighting rates. However, female/calf pairs were never found alone, and it is considered that, within the group, such pairs were unlikely to be preferentially photographed. These females, in particular, were more likely to be seen only in one search area compared to "other" identified dolphins, which included subadults, males and unidentified females. This suggests that pregnant/lactating females are "more" resident than the other dolphins. Some dolphins (by inference predominantly males and/or subadults) were seen in more than one search area, the distance between resightings along the northern Tugela Bank varying from 17 to 70 km. Consistent with the hypothesis that male humpback dolphins are more mobile, a large male humpback dolphin caught in the shark nets at Richards Bay had been previously photographed in the St. Lucia search area. This may also indicate that immigrant animals, being unfamiliar with the layout of the nets, were more prone to capture.

These data appear to indicate some form of segregation between sex and/or age classes. Matrilineal groups are the basic unit of social organization for many mammals (Poole, 1985; Eisenberg, 1986), including, amongst others, bottlenose dolphins (Scott *et al.*, 1990), pilot whales (Shane & McSweeney, 1990) and killer whales (Bigg *et al.*, 1990). Female membership of groups is relatively stable and site fidelity high, while adult males move from group to group. While it was beyond the scope of this study to determine the social structure of the humpback dolphin, it can be speculated that if the social structure of the humpback dolphin is matrilineal, this would support the contention of the subdivision of the northern Tugela Bank into a few home ranges focused on the river systems. The females in particular, resighted more frequently in the same areas, would be the "more permanent" residents within these ranges, with the males and/or subadults occasionally wandering between such ranges.

The relatively few sightings of humpback dolphins outside the northern Tugela Bank together with the seasonality as indicated in the Natal Sharks Board sightings (Chapter 2) and the high relative frequency of persistent movement (i.e. progression) seen in groups suggest that the dolphins seen outside the northern Tugela Bank were involved in "exploratory sallies" or wanderings away from their home ranges. A calf stage II (defined in Chapter 1) was seen in one of the apparently transient groups (Ballito, 20/3/91). It can be inferred from the small size of the calf that the mother was probably present, and this therefore indicates that adult females are not excluded from "exploratory sallies". There may be, however, a relatively small population resident outside the northern Tugela Bank, as indicated by the repeated sighting of a lone humpback dolphin in the Durban area. It should be noted that the Durban harbour was built on a large, natural estuary, and, from the data presented in this study, is therefore a "preferred" area for humpback dolphins.

In Natal, in summary, the humpback dolphin appears to be resident throughout the year along the northern Tugela Bank, and only seasonally and temporarily moves into the areas to the north and south of this bank. Although factors likely to influence this distribution include a wide and shallow continental shelf and low water clarity, and possibly large estuary systems, other factors, including human disturbance, may also affect this distribution.

Despite much time spent searching, humpback dolphins were seen only infrequently, and often eluded the observers shortly after being sighted. Reliability of results, therefore, can only be increased with considerable further investments of time. It is therefore considered that further work should be limited to focusing on and developing aspects of the above study in a particular area where the dolphins are known to occur throughout the year. Of great interest would be the determination of the home range and the social structure of the humpback dolphin. These could each be determined by studying the dolphins within a more limited area than in this study.

CHAPTER 4

POPULATION ESTIMATES OF THE HUMPBACK DOLPHIN ALONG THE NATAL COAST.

4.1 INTRODUCTION

Perhaps the most vital parameter necessary for management of wild populations is the population estimate (Hammond, 1990). A population estimate, together with known or estimated rates of recruitment and mortality, gives an indication of the status of a population. Methods developed to determine the size of a population include a direct count or census, an estimate based on the density of the species derived from surveys and a mark-recapture estimate, determined from individual identification of animals.

As cetaceans can move large distances and are visible only briefly (i.e. only at the surface), direct counts of populations of whales and dolphins are usually not feasible (Gaskin, 1982; Hammond, 1986). The survey technique, based on sightings or acoustics, estimates the abundance of animals in particular areas, extrapolates these data to other, similar areas, and has been widely used to estimate whale populations (Hiby & Hammond, 1990). During the 1940's to 1960's, population estimates were also derived from the catch per unit effort of the whaling ships (Gaskin, 1982). More recently, the photographic mark-recapture technique has been used to estimate populations of, amongst others, humpback whales (Darling, Gibson & Silber, 1983), southern right whales (Best & Underhill, 1990), Dall's porpoise (Miller, 1990) and bottlenose dolphins (Hanson, 1990; Wells & Scott, 1990).

The mark-recapture technique was developed by Petersen (1889), and holds that the total number of individuals marked and released (r) relative to the total population (N) is equal to the proportion of marked animals (m) in a subsequent sample of (n) animals:

$$r/N = m/n$$

More sophisticated versions have since been developed which have been adapted to particular sampling strategies, but all are descended directly from the above model (Begon, 1979). The choice of a particular model for evaluating data depends therefore on its applications and the circumstances of the study. Basic assumptions held by the mark-recapture techniques (Blower, Cook & Bishop, 1981) are that (i) markings are permanent, (ii) marked animals mix randomly with the unmarked, and (iii) time spent sampling is small in relation to the intersampling periods. Difficulties of data collection frequently compromise these assumptions, however, and the precision of results must therefore be assessed through an appraisal of any biases (Begon, 1979).

Given that little is known of the humpback dolphin population in Natal and that concern has been voiced on the status of this population (Cockcroft, 1989), this study was designed to estimate the size of the Natal population and gauge the natality rate.

4.2 METHODS

An SLR camera (Minolta 3000i) with automatic film speed setting with a 70-210mm zoom lens was used until March 1992, when another camera (Minolta X700) with a manually set film speed capability and a 70-300mm lens was obtained. Colour slide film (ISO 100) was used. With the Minolta X700 the film was "pushed" to ISO 400. The film was then over-developed by two stops by a commercial photographic laboratory.

Individual dolphins were identified by visual inspection of photographic slides. Only clear, focused pictures were used and only animals with well-defined and distinct marks were identified positively. Scars, notches, shape and colouration of the fin were found to vary from individual to individual and could be used for identification. Although several individuals were visually identifiable in the field, only photographically verified sightings were included in mark-recapture modelling to avoid sighting bias of prominently marked individuals.

Humpback dolphins caught in shark nets in Natal during the study period were transported to, and stored at, the headquarters of the Natal Sharks Board. The fins of these animals were examined for identification purposes.

Three different methods were used to estimate population size:

(i) Chao M_h mark-recapture model (Chao, 1989) - which solely used the photo-identification data.

(ii) Jolly-Seber mark-recapture model (Jolly, 1965; Seber, 1965) - used to estimate only the size of the Richards Bay sub-population. These results were extrapolated to other areas on the basis of relative sighting rates.

(iii) Petersen mark-recapture model (Petersen, 1889) - in which the net captured animals were taken as a subsequent sample of those originally identified photographically.

The Chao M_h population estimate was determined using the *CAPTURE* program of the Colorado Cooperative Fish & Wildlife Research Unit. The confidence intervals were determined using the method described by Burnham, Anderson, White, Brownie & Pollock (1987) and Chao (1989). The estimates from both the Petersen and the Jolly-Seber models were derived manually.

The total number of identified adults seen consistently with a young calf relative to the size of the total population was used to give a rough indication of the natality rate. Young calves were off-white in colour, approximately one third the length of adults. They often had an apparent difficulty judging the surface when breathing, frequently overshooting, and usually surfaced on the distant side of the presumed mother.

4.3 RESULTS

4.3.1 Photographic identification

Sixty-eight percent of dolphins in a group (the size of which was estimated in the field by counting dolphins in differing positions and having differing sizes, markings and/or colourations) were identifiable. The remaining proportion, predominantly the calves and juveniles, had no markings (Table 4.1). Thus the estimate of the total number of dolphins (i.e. both identifiable and not identifiable) in the group or population (D) can be determined from the number of photographically identified dolphins (I) using the formula:

$$D = I/0{,}68$$

Ninety-six individual humpback dolphins were identified photographically from March 1991 to August 1992 (Fig. 4.1). As only 68% of dolphins were identifiable, it can be estimated that a total of 141 (96/0,68) individual dolphins were seen.

Forty-five individuals were identified and/or re-sighted in the Richards Bay search area (Fig. 4.2). Nine of the individuals seen more than once at Richards Bay were presumed to be females, being accompanied closely and consistently by young calves. The most frequently re-sighted animal, a presumed female, was seen with 36 other identified dolphins during the study. Groups in which she was identified varied between five and 18 animals, and averaged 10,9 $\pm$ 4,6 animals.

Photographic sampling, according to the Leslie test (Leslie (1958) was significantly non-random ($X^2 = 70{,}29$; d.f. = 45; $P < 0{,}02$).

4.3.2 Dolphin population estimates

4.3.2.1 Photographic mark-recapture

From available models in the *CAPTURE* programme, the model which best fitted the data (goodness of fit test: $Chi^2 = 23{,}39$, d.f. = 16, $p > 0{,}1$), was the Chao M_h model (Chao, 1989). The population estimate using this model for identifiable animals along the Natal

Table 4.1 The cumulative number of dolphins seen and identified for all sighting occasions when photo-identification was possible.

	Adults	Juveniles	Calves
Number seen	152	99	27
Number identified	132	57	0

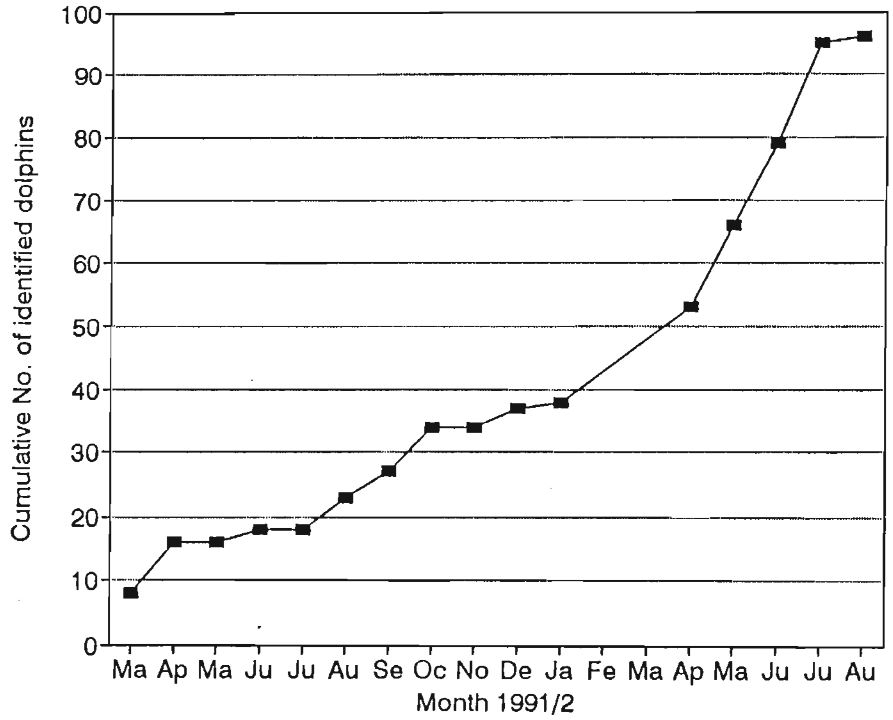

Figure 4.1 Monthly record of the cumulative numbers of humpback dolphins identified throughout Natal from March 1991 to August 1992, inclusive.

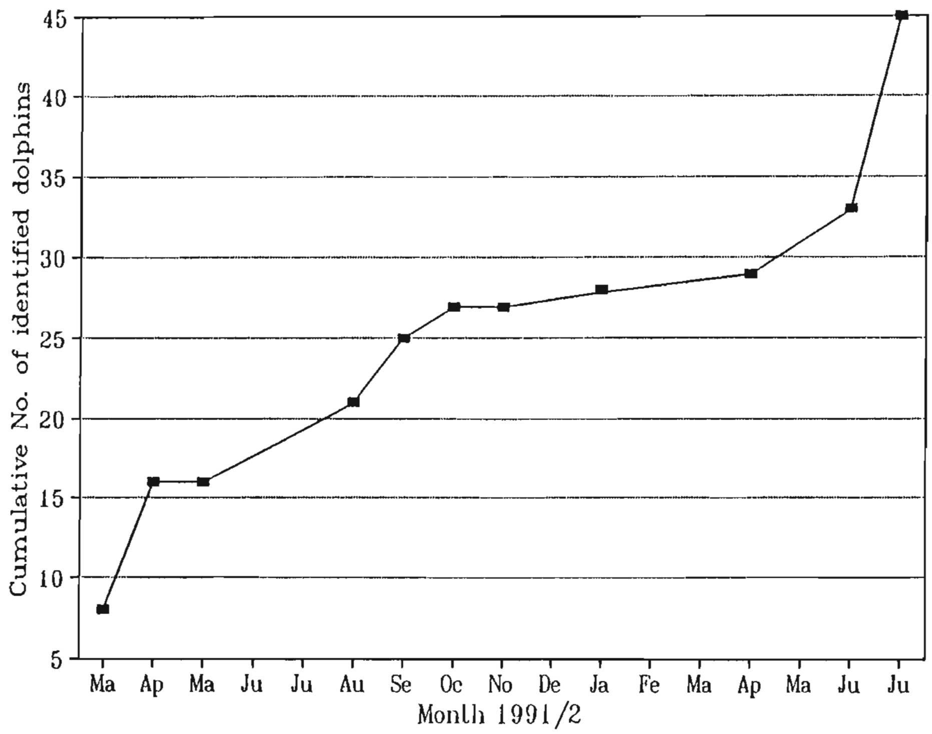

Figure 4.2 Monthly record of the cumulative numbers of humpback dolphins identified at Richards Bay from March 1991 to August 1992, inclusive.

coast was 112, with 95% confidence limits of 91 and 156. The unbiased estimate for all dolphins was thus 164,7, the 95% confidence limits approximately 134 and 229.

The Jolly-Seber estimate of the Richard Bay sub-population (corrected for unidentifiable dolphins to 37,7; 95% confidence limits 19,0 and 56,4) was used in conjunction with the sighting rates of humpback dolphins in each search area (Table 4.2) to determine the relative population sizes in each of the other search areas along the northern Tugela Bank. The estimated size of the (total) population, the sum of the sub-populations in the different search areas along the northern Tugela bank, was 160,7 (approximate 95% confidence limits 81,0 and 240,4).

4.3.2.2 Net-caught dolphins

Thirteen humpback dolphins were captured in shark nets in various localities in Natal during the study period (March 1991 to August 1992). Ten of these were returned to the headquarters of the Natal Sharks Board and examined subsequently for natural markings. Six dolphins (60%) had markings which were considered prominent and distinct, and were assumed, therefore, to have been available for photographic sampling prior to their capture. Five of the individually identifiable dolphins (83%) were recognized from previous field photographs. The Petersen estimate using these data, was 112,8 identifiable animals, corrected to 165,9 (112,8/0,68) for all dolphins in the Natal population.

4.4 DISCUSSION

The population model selected as the best fit for the photo-identification data by the *CAPTURE* programme was the Chao M_h (i.e. heterogeneity) model, and the resulting population estimate was 165 animals (95% confidence limits 134 and 229). In addition to the assumptions listed in the introduction, this model assumes that the population is closed and that capture probabilities vary between individuals (Chao, 1989).

To verify the reliability of this estimate, the population size was re-estimated using variations of the mark-recapture technique, and including different data. The Petersen

Table 4.2 Sighting rate (individuals per hour) of humpback dolphins in the five search areas on the northern Tugela Bank, together with sub-population estimates for each based on the relative sighting rate and sub-population size (Jolly - Seber model estimate) at Richards Bay.

Search area (No.)	Sighting Rate	Sub -Population size
St Lucia (2)	1,53	21,9
Richards Bay (3)	2,63	37,7
Umlalazi River (4)	2,40	34,4
Amatikulu River (5)	2,40	34,5
Tugela River (6)	2,24	32,2
	Total	160,7

population estimate, derived from the net-captured dolphins, was 166 animals. Because some of the dolphins were captured before the photo-identification study was complete, this estimate would probably be biased upwards. Further assumptions held by the Petersen model are that the population is closed and that capture probabilities between individuals are equal.

A third, albeit less rigorous, population estimate of 161 animals was derived in part from the sighting rates obtained from boat searches in different localities (described in Chapter 3). The sizes of the sub-populations in the five different localities on the northern Tugela Bank were estimated by comparing each sighting rate relative to that at Richards Bay, which was the most consistently searched area. The Richards Bay sub-population was estimated at 38 animals using the Jolly-Seber model, which holds the assumptions, in addition to those listed in the introduction, that the population is open and capture probabilities are equal. This model was selected as substantial gain and loss to the sub-population could be shown through detected movements, births and shark net captures in the Richards Bay area.

The last estimate was limited to those dolphins occurring along the northern Tugela Bank, and it may therefore be under-estimated, having excluded those animals seen elsewhere. As discussed below, this bias may be negligible. If not, the Petersen mark-recapture estimate ($1/0{,}68 \approx 2$ animals) or the number of humpback dolphins seen outside the northern Tugela Bank region ($7/0{,}68 \approx 10$ animals), should be added to the total to give an approximate minimum population estimate of between 163 and 171 animals.

The apparent decrease in the rate of identification (Fig. 4.1) evident in August 1992 was derived from a single sampling that month, and was probably not significant. The relatively constant rate of identification thus indicates that not all animals in the population had been identified by the end of the study, and this record could not be used to estimate the size of the population. Based on individual identification of 96 animals throughout Natal, and taking into account that five of these animals were captured in the shark nets, there were not less than approximately 134 individuals ((96-5)/0,68) in Natal by the end of the study.

Each of the above models has several assumptions, and the extent of bias needs to be assessed. Natural markings (including notches and scars) on bottlenose dolphins have been shown to last long periods, possibly for the duration of the life of the individual (Lockyer & Morris, 1990), and the use of natural markings on cetaceans in mark-recapture modelling has been extensive (Wursig & Jefferson, 1990). It was considered that similar markings on the humpback dolphins used in this study would last at least the duration of the study (17 months). Membership and size of groups varied considerably, and the majority (80%) of dolphins sighted in the Richards Bay area was seen at some stage in the group containing the most frequently sighted animal. As not all animals were photographed at each group sighting, the above figure is a minimum proportion. These data suggest that there was considerable mixing between "marked" and "unmarked" animals. Sampling time (the average search lasting 2,7 hours) was small in relation to the intersampling periods. It was therefore considered that the basic assumptions listed in the introduction were largely upheld.

Further assumptions depended on the particular models. The Chao and Petersen models assume that the population was closed. Humpback dolphins were sighted predominantly along the northern Tugela Bank, in north central Natal (Chapters 2 & 3). Elsewhere the occurrence of the dolphins (measured as sighting or capture rates) was considerably lower. In a preliminary genetic study of the Natal population, high levels of inbreeding were found (Smith, 1991). Although the humpback dolphin can move large distances (up to 120 km - Chapter 3), all the evidence suggests that the Natal population is, to some extent, isolated. If, however, the rate of immigration/emigration or births/deaths is not constant (Blower *et al*, 1981), the resulting closed population estimates would be over-estimated (Begon, 1979).

For the Petersen and Jolly-Seber models, a further assumption holds that capture probabilities between "marked" and "unmarked" individuals were equal. Photographic sampling in this study was significantly non-random according to the Leslie test (Leslie, 1958), because re-sighting frequencies did not have a binomial distribution. As described in Chapter 3, adult female humpback dolphins may have a more limited home-range than other sex or age classes and would thus be available for recapture more often. If this was indeed the case, then while sampling may in fact be random, the unequal capture probabilities, or "heterogeneity", could account for the apparently non-random sampling (Begon, 1979; Hammond, 1986). For the Petersen model it was considered highly unlikely that natural markings would directly affect an individual's capture probabilities in the shark nets. However, as described above, the possible segregation between the sexes may have influenced capture probabilities. Despite the more frequent re-sighting of female dolphins in the Richards Bay area (Chapter 3), captures in this locality were predominatly subadult males (Chapter 2). The link, if any, between the sightings and captures of dolphins and their natural markings is therefore obscure. For either the Petersen or the Jolly-Seber models, if the "capture" probabilities were unequal, the population would be underestimated. Slooten, Dawson & Lad (1992) suggested, however, that bias from unequal capture probabilities would be small, and that "a relatively reliable estimate" could be obtained despite possible sampling bias. Hammond (1990), for example, examined the effects due to heterogeneity in a population estimate of humpback whales in the Gulf of Maine, and found that the population had been underestimated by less than six percent.

Further bias may have been introduced to the data through the use of a different camera midway through the project, which was followed by an increase in the rate of identification of dolphins. It was considered, however, based on the following argument, that the bias was, at most, minimal. As the water was usually turbid, preventing the underwater movements of the dolphins being seen, the camera could not be pointed and pre-focused at where the dolphins would surface. The increased magnification of the new lens reduced the depth of field and made focusing more sensitive, thereby increasing the probability of blurring the photograph. The use of a larger lens thus offered no clear advantage. If, however, the number of identifiable dolphins did increase owing to the greater magnification of the new lens, then population estimates based on mark-recapture would be biased upwards. If there was little or no bias from the use of the new lens, then the increased sighting rate evident after April would suggest an influx of dolphins into the Richards Bay area. This was supported by the fact that one of two identifiable dolphins caught in the shark nets during this period had been previously photographed in the St Lucia area.

The estimate which appeared to contradict least the inherent assumptions was that derived from the Chao M_h model, and this estimate, 165 animals, therefore is likely to be the most accurate. The remarkable similarity between this estimate and those based on the different data sources (*viz.* capture of dolphins in the nets (166) and the sighting rates (161)) could be entirely fortuitous, given the inherent biases in all techniques and the wide confidence limits. Alternatively, the close agreement may offer support for the population estimate of approximately 165 animals.

As suggested in Chapters 2 & 3, the humpback dolphin population in Natal may be concentrated predominantly along the northern Tugela Bank. The low mark-recapture estimate for animals outside this region (approximately two animals) and the few dolphins (approximately ten animals) seen during searches (the total time of which approximated that along the northern Tugela Bank) supports this. As a further measure, the sub-population size at each of the net installations south of the northern Tugela Bank was gauged relative to that at Richards Bay, using the average relative capture frequencies (1:48,5 - Chapter 2). The resulting estimate was approximately 38/48,5 = 0,78 animals. The sum total for southern Natal (0,78 x 43 installations) was therefore 33,5 animals. The few captures in southern Natal could, however, have resulted from occasional and temporary forays by humpback dolphin groups away from their home range, in which case this estimate would not be a reliable (resident) population estimate. The relatively high mobility of the groups (Chapter 3) and the seasonality of sightings in southern Natal (Chapter 2) suggest that these groups may have come from, or were going to the northern Tugela Bank, and this was photographically verified in one instance. The population estimate for resident areas, made from data gathered over more than a year, would therefore include those animals which had engaged on temporary forays away from the resident area.

A rough estimate of the birth rate for the humpback dolphin can be determined by the number of calves in the population (Perrin & Reilly, 1984). Because calves could not be individually identified, their number could not be directly counted. Their number was therefore estimated by counting the number of adults which were individually identifiable and presumed to be mothers because of close and consistent association with calves. There were nine presumed mothers identified in the Richards Bay locality. Using the Jolly-Seber population estimate for Richards Bay (n = 38), the birth rate for this area was estimated to be approximately 16% per year. Saayman & Tayler (1979) estimated the birth rate of humpback dolphins in the Eastern Cape as ten percent per annum. Their method of estimation was even less rigorous, and these two estimates cannot be considered significantly different.

The problems associated with working with free-ranging humpback dolphins have been widely reported (Pilleri & Gihr, 1972; Zbinden *et al.*, 1977; Maigret, 1981; Roberts *et al.*, 1983; Ross *et al*, 1994). In this study, amongst other problems, it was found difficult to get close enough to photograph the dolphins, and groups were not infrequently "lost" prior to getting sufficient photographs. Thus, despite relatively frequent sightings of humpback dolphins (61 groups in 136 searches), sampling occasions in which at least some dolphins were identified were limited in number (30), resulting in the wide confidence limits. Experience with the habits of the dolphin certainly helped in photographing humpback dolphins, but their behaviour nevertheless demanded extensive sampling to obtain the required amount of data. Despite these difficulties, the estimate produced is considered to be reasonably accurate because it could be validated using different data and different mark-recapture techniques.

Pilleri & Pilleri (1979) roughly estimated that there were 100 humpback dolphins along 30 kilometers of coastline in the northern sector of the Indus Delta in Pakistan, and they extrapolated this "density" (i.e. 3,3 dolpins per kilometer) to a further length of coastline. In comparison, in Natal there were, on average, roughly 0,3 animals per kilometer of coastline. The dolphins had apparent preferences for particular areas (shallow, turbid water around large estuaries - Chapter 3), however, and thus the relative abundance varied considerably from approximately zero in southern Natal to 1,2 dolphins per kilometer along the northern Tugela Bank. It would, however, be unreliable to draw conclusions from comparisons between these two studies as there are great differences not only in man's utilization of the coastal region, but also between the environments in each study area.

Implications of the population size determined in this study and further work are discussed in the following chapter.

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS

This chapter briefly summarizes the results of the study and discusses the conservation of the humpback dolphin. Recommendations for future work and the protection of the humpback dolphin in Natal are made.

5.1 Summary

Humpback dolphins were found relatively frequently in the shallow, turbid water zone over the wide inshore continental shelf along north central Natal, stretching from the Tugela River mouth to the St Lucia estuary. In this "preferred" region - the northern Tugela Bank, the relatively high re-sighting rates of identified dolphins and the year round occurrence of dolphins together suggest that the humpback dolphin is resident.

Sighting frequencies and the population estimate of dolphins to the south and north of the northern Tugela Bank were markedly lower than those along the northern Tugela Bank, indicating a low density of dolphins. Seasonal variations in sighting rates by the Natal Sharks Board indicated that, in southern Natal, humpback dolphins are to be seen predominantly during summer. This, together with the persistent, directional movement of most of the (few) dolphins seen outside the "preferred" region, was taken to indicate that the majority of dolphins seen outside the northern Tugela Bank were engaged in seasonal forays away from their resident areas.

Within the "preferred" region the dolphins were concentrated around the five river mouths and estuaries, which possibly formed either the core areas of five home-ranges or the focal points of a single home range. There was, apparently, some form of division between the sexes: Pregnant and/or lactating females possibly have a smaller home range than other sex/age classes. Alternatively, they may engage less frequently in forays away from a home range. Using a mark-recapture model which took into account heterogeneity of the capture probabilities, the Natal population size was estimated to be approximately 165 animals.

5.2 Conservation implications

Conservation, as defined by the International Union for the Conservation of Nature and Natural Resources, is the "management of human use of the biosphere so that it may yield the greatest sustainable benefit..."(IUCN, 1980). It follows that, while the death of humpback dolphins through human causes is unfortunate, management of the human "use" is required only if the mortality is not sustainable. It is therefore necessary to determine population trends and thereby assess the status of the population. This can be done either by modelling or through direct observations of the dynamics of the population.

Reilly & Barlow (1984) modeled hypothetical populations and found that the rate of increase of a dolphin population is most sensitive to the calving interval and noncalf survival rate, followed by age at first birth, and is relatively insensitive to changes in calf survival rate. Assuming an annual increase of one growth layer in teeth, Cockcroft (1989) estimated that female humpback dolphins became sexually mature at 10 years of age and had a three year calving interval. With these parameters, the Reilly & Barlow models show a rate of increase ranging between four and minus nine percent per annum, depending on an adult survival rate varying between 0,97 and 0,85 respectively (the highest and lowest reasonable survival rates modeled by Reilly & Barlow). If adult survival is as low as 0,92 to 0,93, (i.e. an adult mortality rate of seven to eight percent of the population per annum) the rate of increase would be zero. Humpback dolphins in Natal are captured in the shark nets at a minimum rate of 7,3 animals per year (Chapter 2), approximately 4,4% of the estimated population of 165 animals (Chapter 4). Estimates of natural mortality for three pelagic delphinids (*Globicephala melas; S. coeruleoalba; S. attenuata*), reviewed in Perrin & Reilly (1984), range from 11,5% to 16,1% per annum. If the natural mortality for humpback dolphins falls within this range, the mortality due to both natural causes and shark net captures may approximate or exceed the rate of increase.

In addition to shark net captures, there are other pressures on the population (chapter 1), including possible pathology from organochlorines (Cockcroft, 1989; Cockcroft, De Kock, Lord & Ross, 1989) and pollution and over-fishing causing habitat degradation (Van der Elst, 1988; 1989; Moldan, 1989), which may further depress the rate of increase of the humpback dolphin in Natal.

It has been suggested, however, that the decrease in the population of large sharks due to capture by the shark fishery has probably reduced predation on local dolphins (Dudley & Cliff, 1993). This might partially compensate for the mortality of dolphins in the nets. There are, however, only two net installations along the northern Tugela Bank where humpback dolphins are resident. While catch statistics indicate a reduction in the shark population at Richards Bay (Dudley & Cliff, 1993b), it is probably localized (Cliff, Dudley & Davis, 1988). Thus any compensatory effect of reduced predation on humpback dolphins in the northern Tugela Bank region may be minimal.

High inbreeding levels were found in the Natal population (Smith, 1991), implying that immigration is limited. The computed rate of immigration into Natal, based on the genetic structure of the population, was less than two animals per generation (Smith, 1991). There are extensive stretches (at least 150 km) of, at most, sparsely populated areas surrounding the northern Tugela Bank. Although humpback dolphins are known to travel up to 120 km (Chapter 3), the large distances to be covered between resident populations (presumably occurring outside Natal) may be a factor contributing to low immigration. Considering that potential immigrants may be captured in the approximately 40 km of nets of the shark fishery in southern Natal (Chapter 2) and that humpback dolphin numbers may be declining in Mocambique to the north (Cockcroft, pers. comm.), recruitment from immigration is unlikely to offset mortality from net captures.

Observations of the Natal population (Natal Sharks Board data - Chapter 2) suggest depletion more directly: From 1984 to 1992 a minimum of 74 humpback dolphins were captured in the Natal shark nets, and the annual sighting rates of humpback dolphins have declined by over half. In the Richards Bay locality where the largest proportion of captures occurred (30 humpback dolphins) sighting rates decreased by 84% during this period. If sighting rates accurately reflect trends in the population, these data suggest depletion. Conflicting with this, however, the capture rates showed no parallel decrease

(Chapter 2). There is, however, a possible explanation as to why a decrease in the population would not exhibit a corresponding decrease in capture rates. As described in Chapter 3, a large river system forms the core or focal point of the home range of humpback dolphins. If this is the case, then as a population is depleted, it would presumably shrink towards the river system, thereby maintaining a constant density in the core area/focal point. If the nets were also located in such an area, then no decrease in captures would be recorded until the population had been depleted to the extent that there were no more dolphins to replace those captured. At Richards Bay, where 53% of all captures in Natal were recorded from 1980 to 1992 (Chapter 2), the nets are set inside and immediately outside the estuarine harbour mouth.

If the above hypothesis is realistic, the capture rates would not be a reliable indicator of change in the size of a population resident in the vicinity of shark nets. Additionally, if some captures were due to immigrant animals coming from robust neighbouring sub-populations, then a decline in capture rates may not be apparent until the entire population was substantially depleted. While the Natal Sharks Board sighting rates may not be without bias (as described in Chapter 2), this record may be a more reliable indicator of change in the size of the population than the capture record.

While there is evidence to suggest that depletion may be occurring, and that this depletion is not unlikely, this evidence is not conclusive. It is therefore not possible to accurately assess the population status, beyond stating that the population is vulnerable and may be decreasing in size. Without an irrefutable case for conservation, it may be taken that until such evidence is available, continued man-induced mortalities are excusable.

This, however, cannot be accepted. Population dynamics of wild animals are notoriously difficult to ascertain, and in a species as cryptic as the humpback dolphin, may not be fully appreciated before the population's possible demise. In the case where man is aware of potential harm to the environment through his activities, the burden of proof should therefore rest on him to show that no long lasting harm is incurred.

I firmly believe, therefore, that the Natal Sharks Board together with the local authorities requesting their services should accept a moral responsibility for the effects of the shark nets. While it may not be economically feasible to remove the nets until such time as sufficient evidence is obtained, I believe that these bodies should show good faith in promoting research into the effects of the shark nets and in adopting measures to protect the affected populations.

5.3 Future work

The most imperative need is to accurately determine the status of the population. According to Perrin & Reilly (1984), the most accurate way to measure net reproduction is to observe changes in total population size concomitant with a known level of removal by humans. If the decrease in the Natal Sharks Board annual sighting rates (over 50% in eight years) are an accurate representation of a parallel decrease in the population, a significant change in the population size would be determinable within four years. If the depletion rate is actually lower, a longer interval before re-estimating the population would be required to observe a significant size change. It is therefore recommended that the population size is re-estimated in four years, and if the population size is not significantly smaller, then the population should be re-estimated after a further four to six years.

High inbreeding levels were discovered in the humpback dolphin population in Natal (Smith, 1990), suggesting that the local population is isolated. If the humpback dolphin population in Natal is part of a southern African species, and not just a local form of the widely distributed Indo-Pacific humpback dolphin, then implications of depletion are more serious. The taxonomy of the dolphin should therefore be revised and a comprehensive genetic study should be done to assess recruitment levels from neighbouring areas.

The behaviour of humpback dolphins is influenced by the substratum type over which the dolphins are swimming (Saayman & Tayler, 1979). A study of the habitat utilization of the humpback dolphin in relation to catch rates in different nets and the substratum type over which the nets are set may indicate some reasons for capture. Consequently advice could be given about the placement of the nets to reduce dolphin captures.

There is currently another photo-identification study on humpback dolphins under-way in Algoa Bay in the eastern Cape, South Africa. There are no shark nets in this area, and the population may be relatively undisturbed. Comparative work on the results of both studies may reveal indicators of "stress" in a population, and this may prove useful in assessing the status of populations not only in South Africa but in other areas as well.

5.4 Protection measures

Assuming that the humpback dolphin population in Natal is vulnerable and may be declining in size, what can be done to reduce man-induced mortalities? Pressures on the Natal population include pollution and shark-net captures. The causal relationship between organochlorine levels and pathology in dolphins is difficult to prove, or indeed quantify (Gaskin, 1982). Mortality of dolphins in the shark nets is, however, quantifiable, and based on previous arguments, may be a substantial factor in the possible depletion of the Natal population. The Natal Sharks Board has been involved in a study to make the nets more noticeable to dolphins (Peddemors, Cockcroft & Wilson, 1991). The study investigated the effects of both passive visible deterrent devices, including aluminium foil, discs and wire and auditory devices such as clangers, rattles and bells. However, the extremely low catch of dolphins per unit effort in the shark nets and the capture of two dolphins in nets containing "deterrents" led to the discontinuation of the experiments.

A more recent development has been the installation of sub-surface "floats" spaced regularly along an experimental section of net (V.M. Peddemors, pers. comm.). The "floats" are acoustically more detectable by sonar than solid objects (D. Goodson, pers. comm.) and may yield some success in the prevention of dolphin captures. However, owing to the low catch per unit effort of the nets, reliable data may take several years to collect. Work is also being done on an "electromagnetic" shark barrier. This is a device which generates an electrical field in the water which sharks appear to be unable to penetrate (Dudley & Cliff, 1993a). It is thought that its effect on teleosts and marine mammals would be minimal. Experimentation on the viability of this device is, however, also expected to take several years (V.M. Peddemors, pers. comm.).

Fifty-three percent of all humpback dolphin catches in Natal (1980 - 1992) occurred in the Richards Bay shark nets, and a further 11% at the Zinkwasi shark nets, both along the northern Tugela Bank (Chapter 3). The remaining captures were spread out amongst the 43 other net installations in southern Natal. It would be expected that the removal of the nets along the northern Tugela Bank would reduce mortality from shark net captures to 1,9% of the population per year. Unfortunately, the human fear of shark attack is out of all proportion to the frequency of its incidence. The implications of removal of the shark nets thus include socio-economic (*viz.* the tourist industry) as well as environmental issues. The outright removal of the nets at Richards Bay and Zinkwasi, therefore, may not be widely sanctioned.

As described in Chapter 3, river systems along the northern Tugela Bank form the focal point or core area of the humpback dolphin home range, the groups spending most of their time feeding, resting and being socially active within a four kilometre radius of a river system. Consistent with this was the higher frequency of captures in the shark nets at Richards Bay, where the nets are in the immediate vicinity of the estuary, than in the Zinkwasi nets, where the nets are positioned eight kilometres south of the Tugela River. In order to reduce the mortality due to net captures at Richards Bay, a possible solution would be to relocate the net installations away from the harbour. If the nets were moved eight kilometres away from the harbour, captures would expectedly decrease to a rate similar to that at Zinkwasi, and the annual captures would thus decrease from approximately 4,4% to 2,4% of the population. If adopted, this proposal would decrease the pressure on the humpback dolphin population in Natal, while the number of netted installations would remain the same.

5.5 Conclusion

This study has produced a basic description of the humpback dolphin population in Natal and a current population estimate. Evidence was presented showing that the population is vulnerable and may be decreasing in size. The evidence is considered to be sufficiently persuasive to recommend the removal or relocation of the Richards Bay net installation to reduce capture rates. Further work to more accurately assess the status of the population is also recommended.

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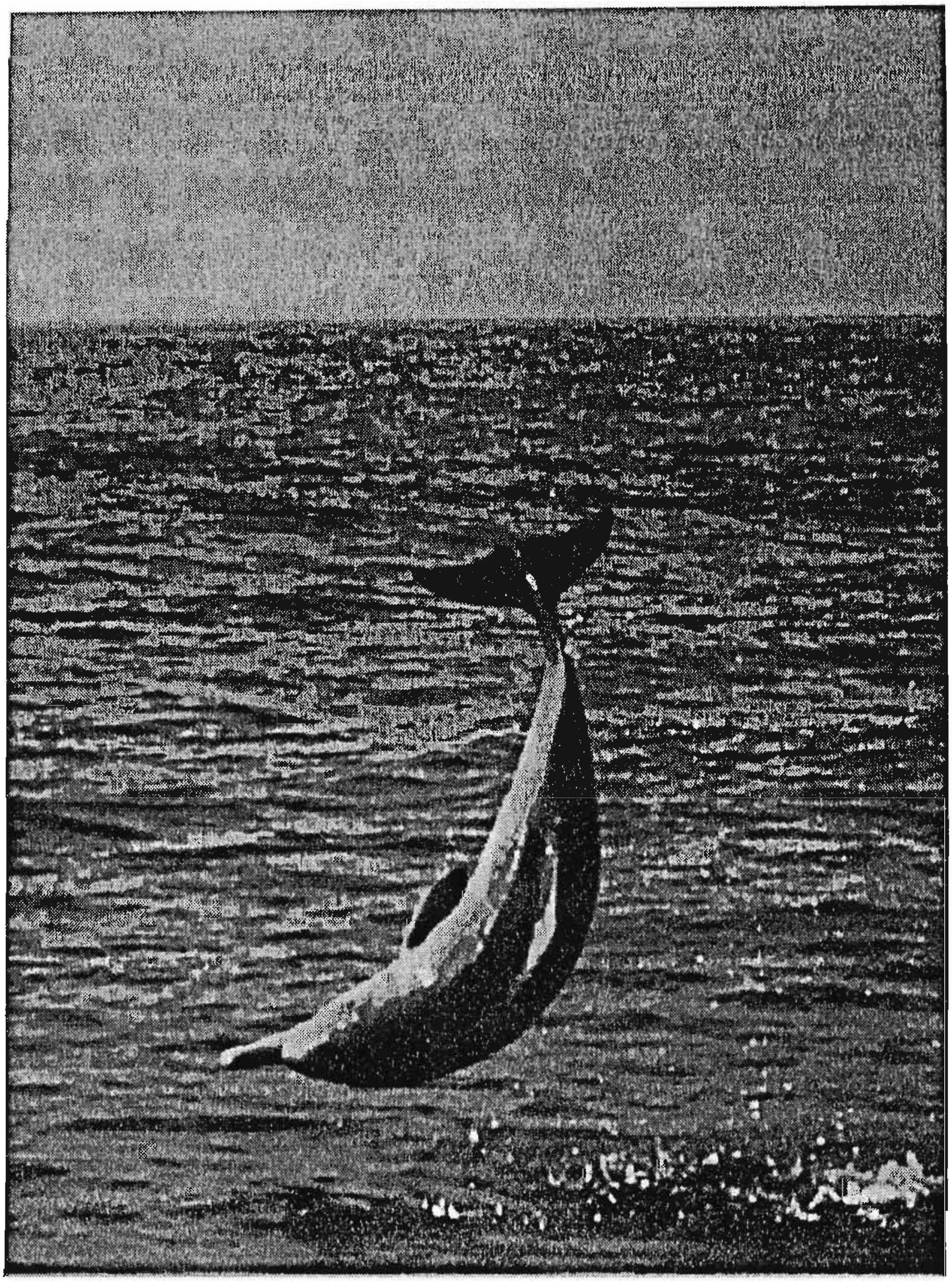

"Tailpiece"