KEITH, MARK

POPULATION BIOLOGY OF HUMPBACK DOLPHINS IN RICHARDS BAY, SOUTH AFRICA

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Population biology of humpback dolphins in Richards Bay, South Africa.

By

Mark Keith

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By

Mark Keith

Supervisor: Doctor M.N. Bester
Mammal Research Institute
Department of Zoology and Entomology
University of Pretoria
Pretoria
0002

Co-supervisor: Doctor V. M. Peddemors
Natal Shark Board
Private Bag X 2
Umhlanga Rocks
4320

Abstract

The population biology of humpback dolphins (*Sousa chinensis*) was investigated in Richards Bay, South Africa from April to October 1998. Water depth determined the distribution of humpback dolphins and no preference for turbid water was evident. Humpback dolphins frequented the study area throughout the year with an average group size of 8.72 (± 5.13). The population is open in nature and is estimated at 213 individuals. Varying degrees of residency and site fidelity were evident for individuals and individuals displayed low levels of association. Captures of humpback dolphins in the Richards Bay shark nets peaked during the winter months. Residency indices for identified dolphins and previous sightings of those caught in the shark nets suggest that unfamiliarity to the shark net installation is a main cause for dolphin capture. The acoustic warning device experiment aimed at determining the effect of habituation on dolphin reactions to pinger sounds was inconclusive; however it appeared that humpback dolphins do not respond aversively towards the pingers. It is recommended that pingers should be deployed in the entire shark net installations to determine their long-term effect on dolphin abundance, distribution and catches. Continued monitoring of the KwaZulu-Natal humpback dolphin population is imperative to detect any change in their current status.

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Chapter 1

Introduction

General overview

Taxonomy

The Indo-Pacific humpback dolphin, *Sousa chinensis*, is found around the coastal rim of the Indian Ocean, through Indonesia, Northern Australia and Southern China in the east (Jefferson, Leatherwood and Webber 1993). This species is morphologically highly variable and at present there are four nominal and disputed species of the *Sousa* genus. According to Parsons (1998), *S. plumbea* (G. Cuvier 1829) and the freckled *S. lentigenosa* (Owen 1866), both range from East Africa to Thailand. *S. borneensis* (Lydekker 1901) occur in the coastal waters of Borneo and Australia, and *Sousa chinensis* (Osbeck 1765), in Chinese waters. Some taxonomic lists recognise only *S. chinensis* and *S. teuszii* (Kukenthal 1892), the latter being found on the western coast of Africa (Atlantic humpback dolphin) (Ross, Heinsohn and Cockcroft 1994).

A study on the phylogeny of the genus *Sousa*, by Cockcroft, Leatherwood, Goodwin and Porter (1997), found a large divergence between *S. chinensis* and *S. plumbea* DNA sequences, indicating a long history of isolation between the regions they represent. Cockcroft *et al.* (1997) obtained results that suggest *S. plumbea* and *S. chinensis* should be regarded as separate species. The phylogenetic trees obtained of all the *Sousa* haplotypes analysed, infer a monophyletic origin, implying that the genus should not be divided. Even though the results presented by Cockcroft *et al.* (1997) suggest dividing the species *S. chinensis* at sub-specific level, the regional genetic differences displayed are sufficient to regard those populations studied as separate management units.

Characteristics

Humpback dolphins are robust in form and characterised by a long beak (Ross *et al.* 1994; Jefferson *et al.* 1993). These dolphins are also readily distinguishable by the notable small, sickle-shaped dorsal fin which is situated upon an elevated mid-dorsal section. This hump, in some populations, is the most characteristic morphological feature, from which the common name "humpback" is derived (Saayman and Tayler 1979). In other populations the ridge or hump appears to be absent or less well developed.

Distinct sexual dimorphism exists in mature dolphins; the asymptotic length and weight for females and males are about 2.4m and 170 kg, and 2.7m and 260 kg respectively (Cockcroft 1989; Ross *et al.* 1994). Males also present more exaggerated ridges on the back and tail stock (Jefferson *et al.* 1993).

Humpback dolphins are born throughout the year, after a gestation period of approximately one year, with a peak in births occurring in summer (Peddemors 1997).

Colour patterns vary according to age and distribution. In most areas of occupancy the calves are lighter coloured and darken with age to become dark or lead grey dorsally and light grey ventrally. According to Ross *et al.* (1994), South African calves are lighter in colour than those found elsewhere. Adults have a distinct dark plumbeous grey dorsal surface, flukes and flippers, with lighter grey appearing on the sides and an off-white ventral surface. In Chinese waters calves are dark grey, becoming paler with age, with sub-adults displaying mottled greyish pink colouration. Adults in turn are pinkish white with a dark eye patch (Ross *et al.* 1994). In some, apparently older individuals, the fin tip and adjacent areas become white (Saayman and Tayler 1979; Ross *et al.* 1994; Parsons 1998).

Group size varies between one to 30 animals, with an average of seven humpback dolphins in a group (Durham 1994a; Karczmarski 1996b; Saayman and Tayler 1979). Group sizes do not usually exceed 13 animals in Port Elizabeth, South Africa (Karczmarski 1996b). Saayman and Tayler (1979) found that humpback dolphin groups are characterised by their temporary nature and fluctuating membership.

Habitat

Humpback dolphins are inhabitants of shallow tropical and warm coastal waters less than 20 metres in depth and enter river mouths, estuaries, and mangroves (Jefferson *et al.* 1993; Ross *et al.* 1994). Saline and often turbid channels leading into mangroves and between sand banks, form a prime habitat for humpback dolphins (Ross *et al.* 1994). Parsons (1998) and Peddemors and Thompson (1994) observed several humpback dolphins feeding in the fresh/salt water mixing zone at the mouths of estuaries and river mouths, in western India and Mozambique, respectively. Durham (1994a) found humpback dolphins occurring in high water turbidity, consistent with estuarine areas having high sediment load. Durham (1994a) found these dolphins in the Tugela Bank region (KwaZulu-Natal (KZN), South Africa), to be in close association with river mouth systems. In contrast, Saayman and Tayler (1979) and Karczmarski (1996b), found humpback dolphins in the Eastern Cape in relatively clear waters with visibility of up to 24 metres.

With shallow rocky reefs being their primary feeding grounds, these dolphins have a very restricted distribution and it seems that water depth is probably the main factor limiting their distribution (Karczmarski and Cockcroft 1997). Throughout their range, these dolphins appear to favour feeding on inshore reef, estuarine and littoral associated fish (Barros and Cockcroft 1991; Cockcroft 1989; Peddemors 1997; Ross *et al.* 1994).

Shark nets and incidental captures

The incidental captures of dolphins in shark nets set off the coast in KZN are causing much concern amongst the public and scientific community. Shark nets are not species specific and a number of harmless species are being captured in these nets. Dolphins, sea turtles and teleosts are also retrieved from the nets. Three species of dolphins, the common dolphin (*Delphinus delphis*), the bottlenose dolphin (*Tursiops truncatus*) and the humpback dolphin (*Sousa chinensis*), form the majority of the dolphin by-catch, off the KZN coast. This may ultimately lead to a decline in population numbers in this region (Cockcroft 1990; Cockcroft 1994). Between 1980 and 1988, 250 bottlenose dolphins;

290 common dolphins; and 53 humpback dolphins were retrieved from the shark nets (Cockcroft 1994). Year round captures of bottlenose and humpback dolphins indicate their year round occurrence in coastal waters. Cockcroft (1990) believes that the inter-annual variation and wide geographic range of common dolphin catches are probably related to the extent and migration of sardines (*Sardinops sagax*).

The shark nets catch an average of eight humpback dolphins per year along the KZN coast (Cockcroft 1990). Recent population studies estimate the population size for KZN to be approximately 165-215 individuals (Durham 1994b), suggesting that ±4% of the population is killed each year in shark nets. This is double the calculated 2% annual sustainable mortality level of a dolphin population (International Whaling Commission 1994).

The fact that 74% of all humpback dolphins are caught in the four northern most shark net installations situated within the Tugela Bank region (90% of which occurs in Richards Bay), further stresses the plight of this dolphin species (Durham 1994a). Thus continued mortalities in the shark nets may lead to the KZN population being under severe pressure. The situation in other areas of the Indian Ocean region seems no better. Although little is known about the measure of human impact on dolphins and about the status of particular populations, there is evidence that at least some populations have been seriously reduced and others may be under considerable stress (Karczmarski 1996b; Karczmarski and Cockcroft 1997).

Progress in the development of warning devices

The most serious danger to dolphins and porpoises around the world is the threat from various forms of gill-net fishing (Kraus, Read, Solow, Baldwin, Spradlin, Anderson and Williamson 1997). Humpback dolphins are the most threatened dolphin species on the eastern coast of Southern Africa (Peddemors 1997). Several man-induced factors contribute to this status, including habitat degradation, high levels of organo-chlorine pollution, and incidental mortalities in fishing nets. One of the potential ways to reduce the number of deaths of marine mammals is the use of acoustic alarms to warn animals about the presence of nets (Jefferson and Curry 1994).

In the past 15 years experiments have been carried out by the staff at the Natal Sharks Board (NSB) to reduce the by-catch of dolphins in the shark nets. Active devices emitting sounds (clangers, rattlers and bell buoys), as well as passive devices were introduced into various nets (Peddemors, Cockcroft and Wilson 1990). Results of the experiment yielded no visible changes in dolphin movement in relation to the installation in question. Two types of active devices were present in a net when two dolphins were caught. It is suggested by Peddemors *et al.* (1990), that the devices have a minimal effect in preventing captures and may even encourage investigation of the sounds. The apparent limitation of the active devices tested suggests that electronically activated devices, which can function under all weather conditions, may prove more efficient (discussed below). In another experiment by Peddemors (1995) air filled keg floats were placed in the shark nets to reflect dolphin sonar signals. These floats were positioned in a 2 metre grid within one net. This net, as well as a control, was placed on one of the preferred long shore travelling routes of bottlenose dolphins in the Durban area. Peddemors (1995) found a significant reduction in speed when the dolphins approached both structures. The changes in the respiratory behaviour of the dolphins approaching the control nets implied that the bottlenose dolphins experienced some difficulty in detecting the obstruction, while the sonar reflectors increased the ease of detection. Although the air-filled keg floats enhanced the detectability of the nets to dolphin sonar, dolphins do not appear to use their sonar continually during travel (Peddemors 1995). It is therefore suggested by Peddemors (1995) that air-filled devices will not decrease the capture of dolphins involved in behaviours not requiring the use of their sonar.

Recently developed acoustic warning devices, which will be referred to as "pingers" in this thesis, are known to be strongly aversive to harbour porpoises (*Phocoena phocoena*), while remaining undetectable to fish (Kraus *et al.* 1997). However, Kraus *et al.* (1997) caution against the testing of the pingers in other situations where odontocetes are threatened by gill-nets, unless careful experimental design and appropriate controls are implemented. The urgency of attempting to reduce human-induced pressures on humpback dolphins, especially shark net captures off the coast of southern Africa, makes this species an ideal candidate for the testing of pingers. The type of pingers deployed were the PICE© porpoise deterrent (PICE© - 970704 - Issue A), acoustic aversive mechanism developed by Loughborough University, United Kingdom. The device produces a variety of wide band signal wave forms, every four to 30 seconds (300 ms pulse length), including frequency sweeps between 20 kHz and 160 kHz with a source level of 145 dB (PDM data sheet No. PDM/SL/5039). Pinger data were gathered during the deployment of these pingers (July 1998 to November 1998) in the shark net installation at Richards Bay. The pingers were deployed on a random weekly basis and were placed randomly in the two southern-most at Richards Bay.

Aims

This study aimed to collect the data necessary to assist in sustainable management of the humpback dolphin *Sousa chinensis* population while still offering safe bathing at Richards Bay. It is therefore essential that a better understanding of the population biology of humpback dolphins around the shark nets is obtained. This will ascertain the impact of the incidental catches on the humpback dolphin population in Richards Bay and determine if pinger deployment may reduce their mortality.

The study was conducted simultaneously with a behavioural study (The behaviour of the humpback dolphin *Sousa chinensis* at the Richards Bay shark nets: a test of pinger efficacy, by S. de la Mère (1999; MSc thesis)) and forms part of the Richards Bay Humpback Dolphin Project.

Objectives

1. To investigate the effect that environmental factors may have on the population dynamics of the humpback dolphins within the Richards Bay area.

2. To investigate the historical capture data and ascertain the impact of ongoing catches at the present capture rate.

3. To calculate an estimate of the population size for humpback dolphins within the Richards Bay area.

4. To investigate group dynamics and associations to allow greater insight into the structure of the humpback dolphin population in the Richards Bay region.

5. To calculate site fidelity (residency index) of identified humpback dolphins within the Richards Bay study area and to facilitate further analysis on the effect of pingers as a contribution to a related project.

6. To investigate home ranges and movement patterns of the humpback dolphins within the study area as well as other areas of KZN.

In order to achieve the above mentioned objectives, the following research questions were posed:

- Do environmental factors influence the dynamics of the population?

Collection of biotic and abiotic data throughout the study area, such as water visibility, water temperature and ocean depth, were used to correlate any noticeable environmental differences in area utilisation of humpback dolphin groups found in the Richards Bay area (Chapter 2).

H_o: Environmental factors do not affect the distribution and/or dynamics of humpback dolphins.

- Is any temporal effects of continued catches evident in the catch trends?

The historical catch data, obtained courtesy of the Natal Sharks Board (NSB), were used to determine any existing trend in dolphin catches over the period that the shark nets have been installed off Richards Bay (1980-1998). This installation is one of the few that has been managed by the Natal Sharks Board since deployment - thus the recorded history is far more reliable. Population details, gained from this study, were incorporated to determine any effects that continued catches may have on the population (Chapter 3).

H_o: Continued catches do not affect the humpback dolphin population

- What is the nature of the humpback dolphin population within the Richards Bay region?

Regular boat-based searches for humpback dolphins were made (weather permitting) to photograph the humps and fins of all animals encountered. Using photo-identification methods, a rate of discovery of identified animals was established. The shape of this curve will determine the nature of the population ("open" or "closed") (Chapter 4).

H_o: The humpback dolphin population of Richards Bay shows minimal migration and may be considered a closed population.

- What is the estimated population size of humpback dolphins at Richards Bay?

Using photo-identification mark–resight techniques (or mark-recapture), the population size was estimated (Chapter 4).

- Is there a noticeable difference in the utilisation (site fidelity) of certain areas by different individuals?

Site fidelity was investigated by dividing the study area into one kilometre strips stretching from New Mouth in the south to the Lighthouse in the north. A residency index (RI) was calculated for identified individuals, using photo-identification methods within the different areas (strips) of the study area (Chapter 5).

H_o: Humpback dolphins do not display any fidelity to a particular site or area.

H_o: Residency indexes are similar for all the humpback dolphins seen in Richards Bay.

- Do humpback dolphins demonstrate any noticeable home ranges and movement patterns for the duration of the study period?

Once the RI and site fidelity of identified individuals have been established, home ranges and movement patterns were ascertained for each individual (Chapter 5).

H_o: There is no difference in home range and movement patterns of individual humpback dolphins.

- What is the effect of activated pingers on the RI, home ranges and movement patterns of humpback dolphins in Richards Bay?

The effects of the pingers were determined with regard to individuals familiar to the netted area (high RI), in contrast to individuals unfamiliar to the installation (low RI). The RI, site fidelity and home ranges were compared for the periods in which the pingers were active or passive. The effects of the pingers were quantified in terms of variation in any of the above mentioned factors (Chapter 5).

H_o: Activated pingers do not have any effect on the RI, site fidelity, movement patterns and home ranges of humpback dolphins around the shark nets.

Rationale

To understand the impact of the continued annual mortalities caused by the shark nets, the collection of detailed humpback dolphin population data is crucial. Any emerging pattern from the data obtained, with inclusion of the behavioural study (de la Mère 1999), will hopefully reflect the state of the humpback dolphin population frequenting the Richards Bay area. Such data, as well as data from the pinger experiment, will contribute to the making of qualified decisions, regarding the sustainable management and conservation of the KwaZulu-Natal humpback dolphin population in particular, and for the species as a whole.

Chapter 2

Biology of humpback dolphins in Richards Bay

Introduction

The advantage offered by various habitats, food resources, lack of competition and protection from the elements and predation, assemble groups of animals into a combination of densities (Durham 1994a). Benefits from only one area may not be sufficient to provide the necessary requirements for survival and reproduction, and movement may occur between different areas, giving rise to temporal changes in densities (Gaskin 1982).

Seasonal and environmental changes are associated with migratory behaviour in many cetaceans (Cockcroft 1994; Saayman and Tayler 1979). As cetaceans can move large distances and are only briefly visible when they surface, observations and photographs from boats represent a practical approach to study groups of dolphins for the majority of species in most areas (Würsig and Jefferson 1990). It is furthermore evident that some species of cetaceans are more easy to study, whereas other species, including the humpback dolphin, are relatively rare and particularly cryptic (Durham 1994a). The determination of the status and ecological requirements of these little known species is of particular importance, as population depletion in conjunction with mass habitat destruction, usually go unnoticed and unchallenged.

This chapter deals with the correlation of the sightings of humpback dolphins with collected environmental data within the study area to provide better insight into the habitat requirements and preferences of these dolphins within the Tugela Bank region. Data obtained from the study are compared with other studies and their findings (Durham 1994a; Karczmarski 1996b).

Materials and Methods

Study area:

The study area situated at Richards Bay (28° 48' S, 032° 06' E), on the eastern coast of KwaZulu-Natal, stretched from New Mouth (Mhlatuze river mouth north of Durnford Point) in the south, to the Richards Bay lighthouse in the north and did not exceed four miles offshore (Figure 2.1). KZN has a continental shelf, which is narrow and steep, but in some areas the shelf extends out to sea for a considerable distance. The coastal area around Richards Bay is situated on the Tugela Bank, where the 15 metre isobath extends further offshore. The shelf reaches a maximum width of approximately eight kilometres off the Port Durnford Beacon. According to Durham (1994a) the sediment pattern along this bank indicates vigorous wave induced turbulence at the seabed, and the inshore waters in this area are generally turbid. The Agulhas current, a warm southward flowing current, runs just offshore of the shelf break, markedly affecting the physical and biological parameters of the shelf waters (Durham 1994a).

Field procedures:

A five metre semi-rigid inflatable boat was launched, depending on the weather, to locate and follow humpback dolphins in the Richards Bay region during the period April to October 1998.

Searches were conducted soon after sunrise to reduce the impact of wind. On leaving the harbour area, the netted area was searched for humpback dolphins. Searches then followed parallel transect lines up or down the coast. Once the end of a transect (end of the study area) was reached, the transect line was moved offshore (or visa versa) approximately 500 m from, and parallel to, the previous transect and the search was continued to the start of the previous transect line, environmental conditions permitting.

The first humpback dolphin group sighted was followed. During dolphin follows, real time, exact location (using a Garmin II-Plus Global Positioning System) and school size were recorded. School size was estimated using positions of surfacing, size

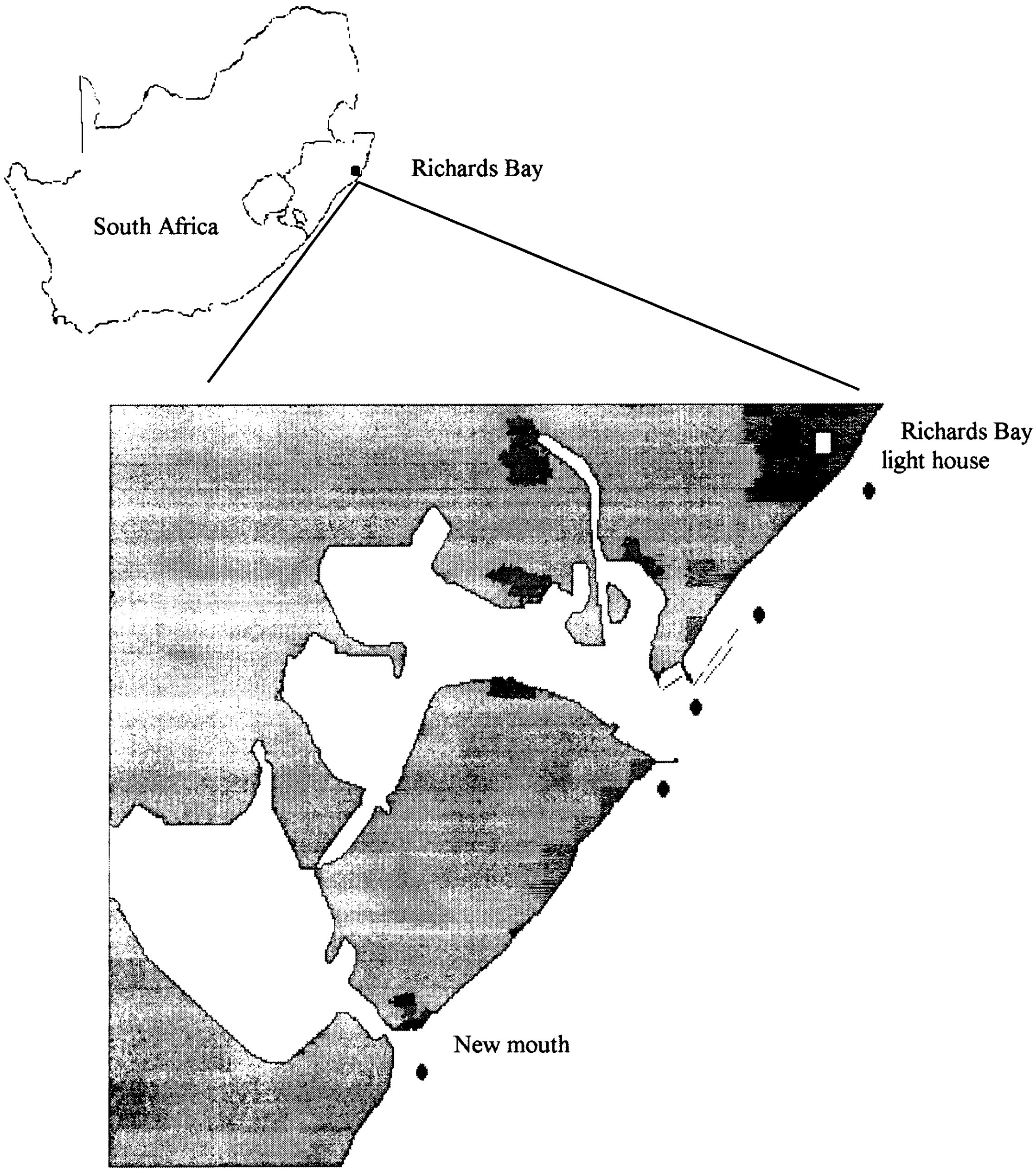


Figure 2.1 The study area situated at Richards Bay (28° 48' S, 032° 06' E), on the eastern coast of KwaZulu-Natal, South Africa. It stretched from New mouth (Mhlatuze river mouth north of Durnford Point), in the south, to the Richards Bay lighthouse in the north, not exceeding four miles offshore. The five set locations where water data were collected are indicated by black dots (•).

of individuals, markings, colouration and hump size. Photographic procured group size estimates were compared to the above mentioned field group size estimates. Individuals were classified as: calves, juveniles or adults as defined by Durham (1994a) and Karczmarski and Cockcroft (1997). In some animals, apparently older individuals, the fin tip and adjacent areas become white, and is subsequently called a "white tip".

Searches were abandoned in sea states greater than three, in accordance with international survey techniques (Leatherwood and Show 1980). Environmental data (sea state, swell height, cloud cover and wind direction) were collected at the start of each launch. Cloud cover was estimated in octas. Other environmental data such as water visibility (using a secchi disk) and water temperature (surface- and subsurface temperature (measured at a depth of five metre)) were noted during searches at five set locations (Figure 2.1). During dolphin follows, water temperature and water visibility were noted on the hour every hour. Water depth was averaged for the one kilometre grid placed over the study area (Figure 2.2), to facilitate site fidelity analysis, using chart datum depth obtained from hydrographic charts (SAN 1032).

Data analysis:

The study area was divided into three regions: northern part, the harbour mouth and the south (Figure 2.2). Further division of the study area into one kilometre zones parallel (zones one to six) and longitudinal (blocks d to p) to the shore was carried out to facilitate analysis. The number of sightings per one kilometre block was divided into categories of: one to five, six to ten, 11 to 15 and more than 16 sightings, for distribution of sighting analysis. The collected environmental data were not normally distributed and could not be transformed to normality. Thus Kruskal-Wallis one way analysis of variance by ranks (Zar 1984) was used to identify possible temporal and spatial differences in the environmental data and group sizes. Chi-squared analysis (Williams 1993) was used to analyse variation between expected and observed values for dolphin group sizes and spatial and temporal distribution of dolphin sightings. A Student *t*-test (Zar 1984) was performed to analyse field group size estimates in comparison with photographically procured group size estimates.

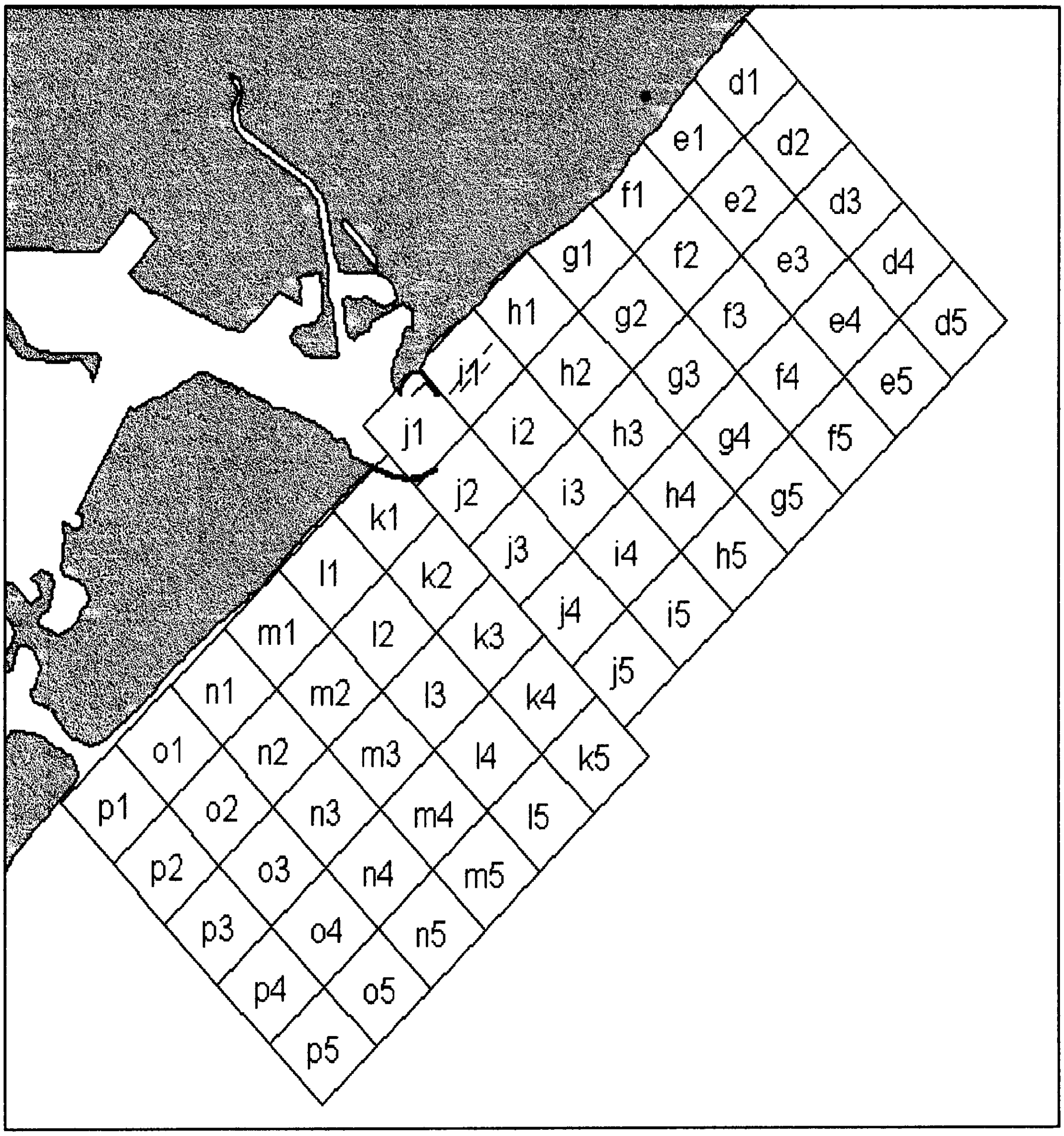


Figure 2.2 The study area divided into one kilometre grids. Zone *d-h* were classified as the northern region of the study area, with *i-k* as the harbour mouth area and *l*-p the southern region of the area

Results

During the period April 1998 to the end of October 1998, 73 launches took place, with 76 dolphin groups (varying between one to 20 individuals) followed. During the above mentioned period environmental conditions allowed two launches in one day, on six occasions, which resulted in a total of 79 searches of the study area. Sixty eight of these searches resulted in photographic follows where satisfactory photographs were taken to identify individual dolphins. Table 2.1 presents the number of launches for every month during the study period, including the number of successful launches, together with the amount of time spent in the vicinity of dolphins. Most launches took place during June, the month that the most time was spent with the dolphins (Table 2.1).

The average group size for the duration of the study was 8.72 (± 5.13) (Table 2.2). No significant difference in average group size when comparing months was found (Kruskal-Wallis ANOVA; H (6, n = 60) = 7.44, ns).

Large aggregations of dolphins (more than 15) were observed during most of the months except in October when the maximum individuals sighted in one group was 10 dolphins, which is smaller in comparison to other months. A significant difference between the field estimated group sizes and the photographic procured group size estimates (Student *t*-test = -4.129; df = 54; P = 0.000127) was found.

Ten dolphins ("females") were consistently photographed and identified to be in close association with young juveniles or calves. Young calves/new born calves were frequently seen during October. Eight "white fins" were photographed within the study period. Only one humpback dolphin was often found to be solitary (n = 7).

Table 2.1 Table containing launch data with number of successful launches and time spent with dolphin groups. The number of photographic follows per month are indicated in brackets.

Month	Number of launch days	Number of successful launches	Success rate (%)	Time spent with dolphins (hh:min)
April	8	5 (5)	62.5	10:52
May	8	8 (8)	100	17:30
June	18	14 (16)	77.7	24:41
July	11	9 (14)	81.8	20:59
August	13	7 (8)	53.8	14:38
September	7	6 (8)	85.7	11:25
October	8	6 (9)	75.0	16:35
April to October	73	55 (68)	75.3	115:40

Table 2.2 Average estimated group size (average ± standard deviation) for humpback dolphins in Richards Bay with the maximum number of individuals per group sighted per month.

Months	Average	Maximum
April	6.17 ± 5.47	17.00
May	7.44 ±3.61	14.00
June	9.93 ±6.46	20.00
July	8.70 ±2.54	15.00
August	11.00 ±4.93	17.00
September	9.17 ± 7.60	20.00
October	6.67 ±2.66	10.00
April to October	8.72 ± 5.13	20.00

Environmental conditions:

Table 2.3 presents environmental conditions measured at the five locations in the search area. The table contains the average (± standard deviation) and maximum values for each of the sample methods. Average water visibility (Table 2.3a) was not related to dolphin presence, with the exception of the New Mouth region of the study area where visibility was significant lower (Kruskal-Wallis ANOVA: H (5, n = 282) = 13.67437; $p < 0.05$). No significant difference was found between the six sample locations for water surface temperature (Kruskal-Wallis ANOVA: H (5, n = 243) = 5.011649, ns) (Table 2.3b), and sub-surface temperature (Kruskal-Wallis ANOVA: H (5, n = 141) = 9.5105, ns) (Table 2.3c).

Water visibility (Table 2.4a), surface and sub-surface temperature (Table 2.4b and Table 2.4c respectively) varied significantly between months. October had the lowest water visibility, while June exhibited the highest average water visibility (Table 2.4a). No significant differences existed between the measured visibility during June and August, and between October and May (Table 2.4). October in turn differed significantly from September (Table 2.4a).

Water surface temperature was significantly higher during the beginning of the study (April and May) than June to August, with an increase during October (Table 2.4b). The lowest surface and sub-surface temperature measurements were taken during July. No significant differences were evident between surface temperatures from July to October (Table 2.4b). Similar results were found for the sub - surface temperature sample analysis (Table 2.4c).

Environmental data collected at the start of every search are displayed on a monthly basis in Table 2.5. April had the lowest observed sea-state, while July exhibited the lowest average wind speed. The highest average cloud cover was found during October; the lowest during June. No significant difference was found among monthly wind speed (Kruskal-Wallis test: H (6, n = 234) = 13.59, ns) and sea state (Kruskal-Wallis test: H (6, n = 234) = 11.28; ns) measurements, while the analysis for variation in monthly cloud cover (Kruskal-Wallis test: H (6, n = 234) = 131.28; $p < 0.01$) and monthly swell height (Kruskal-Wallis test: H (6, n = 234) = 21.63; $p < 0.01$) was

Table 2.3a. Water visibility measured at five different locations (average ± standard deviation) in the study area as well as in the vicinity of humpback dolphins. Results for the Kruskal-Wallis ANOVA of water visibility measurements between sample areas. No letters in common denote significant differences at $p < 0.05$.

Visibility	n	Average	Maximum	$p < 0.05$	Average rank
New mouth	48	2.24 ± 1.42	5.7	b	118.71
South breakwater	30	2.91 ± 1.6	6.4	ab	122.98
Southern end of nets	49	3.22 ± 0.4	9.0	ab	132.61
Northern end of nets	40	3.22 ± 1.7	7.6	ab	134.63
Lighthouse	27	4.14 ± 2.69	11.0	ab	155.57
Dolphins present	88	4.37 ± 2.72	10.0	a	164

Table 2.3b. Surface temperature measured (average ± standard deviation) at five different locations in the study area as well as in the vicinity of humpback dolphins.

Surface Temperature	n	Average	Maximum
New mouth	25	21.20 ± 1.08	23.0
South breakwater	25	21.44 ± 0.93	23.2
Southern end of nets	44	21.02 ± 3.08	23.1
Northern end of nets	37	21.05 ± 3.37	23.2
Lighthouse	24	21.35 ± 1.00	23.3
Dolphins present	88	21.19 ± 0.98	24.0

Table 2.3c Sub-surface temperature (5 m below surface) taken at five different locations in study area as well as in the vicinity of humpback dolphins (average ± standard deviation).

Sub surface temperature	n	Average	Maximum
New mouth	25	21.02 ± 1.20	22.9
South breakwater	24	21.27± 0.98	22.9
Southern end of nets	43	20.89 ± 3.11	23.1
Northern end of nets	35	20.90 ± 3.47	23.1
Lighthouse	24	21.15 ± 1.08	23.3
Dolphins present	12	21.20 ± 1.27	22.5

Table 2.4a Results for the Kruskal-Wallis ANOVA of water visibility measurements between months (average ± standard deviation). No letters in common denote significant differences at $p < 0.01$.

Months	n	Average	p<0.01	Average rank
April	44	2.6 ± 1.4	bcd	77.86
May	31	2.6 ± 1.4	bde	61.48
June	32	5.6 ± 2.0	ad	135.28
July	27	4.3 ± 2.6	bcd	89.03
August	17	5.0 ± 2.3	acd	118.88
September	5	3.3 ± 1.5	d	81.96
October	16	1.7 ± 1.3	e	23.90

Table 2.4b Results for the Kruskal-Wallis ANOVA of surface temperature measurements between months (average ± standard deviation). No letters in common denote significant differences at $p < 0.05$.

Month	n	Average	p<0.05	Average rank
April	31	22.4 ± 0.7	a	125.44
May	32	22.5 ± 0.4	a	128.28
June	32	21.4 ± 0.6	b	73.98
July	27	19.9 ± 3.4	c	32.74
August	17	20.4 ± 0.3	c	30.91
September	5	20.5 ± 0.5	bc	39.30
October	16	21.1 ± 0.8	c	12.06

Table 2.4c Results for the Kruskal-Wallis ANOVA of subsurface temperature measurements between months (average ± standard deviation). No letters in common denote significant differences at $p < 0.05$.

Month	n	Average	p<0.05	Average rank
April	31	22.3 ± 0.6	a	122.97
May	31	22.3 ± 0.4	a	123.73
June	29	21.1 ± 0.7	b	70.74
July	27	19.1 ± 4.2	c	33.93
August	17	20.2 ± 0.3	bc	29.56
September	5	20.3 ± 0.3	bc	40.80
October	16	20.7 ± 0.4	bc	57.78

Table 2.5 Measured environmental (average ± standard deviation) conditions for the different months of the study.

	Sea-state	Wind speed (knots)	Swell height(m)	Cloud cover (octas)
April	1.29 ± 1.11	3.96 ± 3.31	0.49 ±0.54	1.43 ± 2.51
May	1.75 ± 0.62	6.18 ± 4.31	0.66 ± 0.48	3.09 ± 2.84
June	1.95 ± 0.59	5.57 ± 3.06	0.63 ± 0.51	0.85 ± 1.14
July	2.17 ± 0.39	3.83 ±2.38	0.79 ± 0.33	2.33 ± 3.52
August	1.83 ±0.39	4.17 ± 2.22	0.67 ± 0.33	2.42 ± 2.64
September	2.42 ± 0.90	7.38 ± 6.16	0.77 ± 0.36	2.92 ± 3.48
October	2.08 ± 0.29	3.75 ± 2.50	0.79 ± 0.33	5.17 ± 2.86

significant. Average swell height was the lowest during April, increasing as the study continued. July exhibited the largest swell height.

For the whole study period, humpback dolphins were observed on average in a water depth of 13.8 m (S.D. ± 5.7). The maximum average water depth dolphins were seen travelling in was during July where individuals ventured out to 31.8 m (Table 2.6) nearly five kilometres offshore. No significant difference (Kruskal-Wallis test; H (6, n = 299) = 7.84; ns) existed amongst the different months for the depth analysis.

On six occasions dolphin groups were found north of the harbour mouth, 40 sightings were made in the harbour mouth area, while 30 groups were sighted in the southern part of the study area. There was a significant difference in the observed and expected sighting rate for the three different areas (north, south and harbour mouth) (χ^2 = 9.35, df = 2, p < 0.0093). Fewer groups of humpback dolphins were seen and followed than expected in the northern region (*d* to *h*), while more groups of dolphins were seen/followed in the harbour mouth and southern region of the study area regions (blocks *i* to *p*). Most of the follows in the north usually lead to the area of the effluent pipeline situated three to four miles offshore (Figure 2.2; block *g3*). A non-uniform distribution of humpback dolphin sightings was apparent for offshore zones (zone one to four) as well as long shore areas (blocks *d* to *p*). Statistical analysis yielded significant differences in the offshore zones (χ^2 = 12.16; df = 4; p < 0.05) as well as the long-shore distribution of sightings (blocks *d* to *p*) (χ^2 = 28.97; df = 12; p < 0.01) (Figure 2.3). Humpback dolphins were seen more often closer inshore (zones one and two, Figure 2.3) than in the offshore zones.

Table 2.6 Average (± standard deviation) and maximum chart datum depths for monthly dolphin sightings.

Months	Average	Maximum
April	13.6 ± 5.1	21.7
May	12.4 ± 5.6	20.8
June	13.5 ± 5.5	21.7
July	14.0 ± 6.8	31.8
August	14.2 ± 5.1	20.8
September	13.7 ± 4.8	20.8
October	15.5 ± 5.2	25.0
April-October	13.8 ± 5.7	31.8

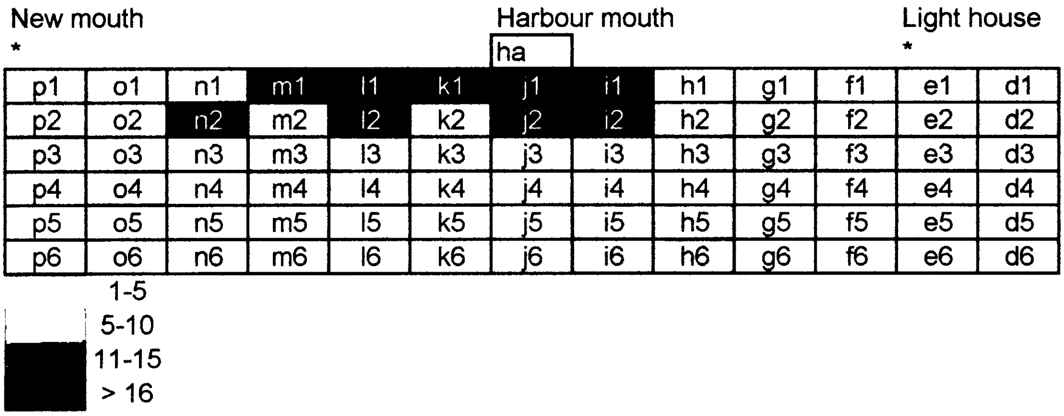


Figure 2.3 Matrix of one kilometre grids of study area indicating the distribution of humpback dolphin. Different colours indicate categorised sighting groups.

Discussion

Humpback dolphins were frequently seen in the Richards Bay area throughout the year as evidenced by the success rate of humpback dolphin follows (75.3%, Table 2.1). In the Algoa Bay region, bottlenose and humpback dolphins were relatively common and could be seen throughout the year (Karczmarski 1996a), with the numbers declining during winter. No such pattern was evident for the present study.

The differences between estimates of field group size and photographic procured group size, emphasise the violation of the assumption for equal probability of capture for population estimates (Pollock, Nichols, Brownie and Hines 1990) (see Chapter 4). During this study, certain individuals were more easily approached and easier to photograph while other individuals and groups remained skittish and veered away from the boat as soon as one came close enough to photograph them. Difficulties of data collection frequently compromise the assumptions implicit in population estimation from photo-identification and the precision of results must therefore be assessed through appraisal of any biases.

The mean number of 8.72 individual (± 5.13) humpback dolphins in a group (present study) follows Gaskin (1982) who states that inshore species like *Sousa*, *Tursiops* and *Phocoena* have schools of quite small average school size, although some seasonal and diurnal periodicity could have an effect. The average number of dolphins observed by Saayman and Tayler (1979) per sighting ranged between 3.9 (S.D. ± 1.0) in autumn and 13.6 (S.D. ± 2.4) in winter, a similar increase being recorded during the winter months for humpback dolphins (present study). Saayman and Tayler (1973), in contrast, found the mean number of humpback dolphins sighted in Plettenberg Bay to be 6.6 ± 1.4 individuals per sighting. Karczmarski, Cockcroft, Mclachlan and Winter (1998) determined a mean group size of seven dolphins (± 2.5), and rarely larger than thirteen animals. Durham (1994a) found average group size of 5.1 (± 3.1) from historic sightings of humpback dolphin groups in Richards Bay, compared to 5.0 (± 5.1) animals elsewhere. The photographic surveys of Durham (1994a), yielded groups sizes from one to 18 animals, with an average of 6.7 (± 5.3) animals, while Parsons (1998) observed a mean group size of 2.6 (± 2.1) animals which was congruent to other findings in Australia and Hong Kong (Parsons 1998).

The ten “females”, with calves in close attendance, which were seen frequently within this study, suggests that the Richards Bay area may have preferred environmental conditions suitable for a nursery area for most of the year (Durham 1994b). Karczmarski (1996b) and Peddemors (1997) stated that the majority of humpback dolphin births occurred in summer, a similar tendency being observed (an increase in the number of new born calves observed during October) in the present study. It is still unknown whether the increase in sightings of young calves continued for the remainder of summer, due to the termination of the current project.

Parsons (1998) found that when juveniles were present in groups of humpback dolphins, there were usually "white fins" accompanying the group. Usually only one "white fin" was present in a group (Parsons 1998), a pattern not manifested during the present study. Similarly, previous studies have encountered a high proportion of solitary animals (15.4 - 20 % of follows) (Parsons 1998; Durham 1994a; Karczmarski 1996b), not in line with the present study seeing that only one particular dolphin tended to be solitary (9% of all follows) and occasionally linked up with larger schools or groups. Even then the individual remained solitary within the larger group. On three occasions, the above mentioned dolphin was seen with a young calf of presumably another female. Karczmarski and Cockcroft (1997) also found that one particular individual frequented Algoa Bay, with infrequent and weak associations with other humpback dolphins.

Environmental conditions:

This study indicated that water clarity did not influence dolphin presence. The mean visibility was not significantly higher while dolphins were followed, compared to the other measurement areas (Table 2.3a) except for New Mouth. The turbidity of the New Mouth area is most likely due to the Mhlatuze lagoon depositing a lot of silt and sediment throughout the year. Furthermore, the low visibility found at the South breakwater sample area is the result of dredging operations to maintain the dredged depth for shipping purposes. Davis, Fargion, May, Leming, Baumgartner, Evans, Hansen and Mullin (1998) believed that the discharge of the Mississippi River delta enhanced the productivity associated with river discharge, which in turn increased the abundance of certain prey species, which attracted cetaceans. The preference of humpback dolphins for turbid water (Durham 1994a), which is at odds with the present study, cannot be explained.

The lowest visibility which was recorded during October (compared to the other months) can most likely be attributed to an increase in rainfall influencing the off flow of the rivers situated in the area, decreasing the water clarity. Rainfall in KZN occurs predominately during the summer months, November to March (Hunter 1988), which explains the high water clarity measured during the low rainfall months of June to August.

Humpback dolphins were seen in both clear and heavily turbid waters, especially in Maputo Bay where they occurred in close proximity to mangrove areas (Guissamulo and Cockcroft 1997). Fishermen in Mozambique reported seeing humpback dolphins some distance up the N'Komati river on the incoming spring tide (Guissamulo and Cockcroft 1997). Durham (1994a) also found that humpback dolphins tend to associate with turbid waters on the coast of KZN. Karczmarski *et al.* (1998) recorded humpback dolphins in a wide range of water clarity (min. = 2.25 m visibility; max. = 12.0 m visibility) with no apparent preference for any water clarity conditions. Karczmarski and Cockcroft (1997) state that the apparent preference for turbid waters observed in humpback dolphins in some areas, may be a secondary result of their preference for an inshore coastal habitat and distribution of their prey. With increased rainfall in summer, river lagoons break their banks and release increased abundance of estuarine-associated fish into the marine environment. An increased abundance of prey species will attract humpback dolphins to the turbid waters of large estuarine systems, such as Richards Bay or to clear water as described in Karczmarski and Cockcroft's (1997) study. The varied turbidity associations/preferences of humpback dolphins, suggest that water clarity may influence the relative density of the dolphins but do not influence the limit of their distribution (Durham 1994a).

The range of the Sarasota Bay, Florida, bottlenose dolphin population was influenced more by water temperature than ocean floor topography (Hansen 1990). However, differences in surface and sub-surface temperature between sample areas did not result in significant differences in preferences of humpback dolphins for the present study. Saayman and Tayler (1979) found humpback dolphins to tolerate water temperature ranging between 15 - 20°C and the average annual sea surface temperature varies approximately 4°C, in KZN, with a high of about 25°C in February (Schumann

1988). Monthly temperature variation in surface and subsurface measurements varied in a similar fashion, suggesting that temperature regimes were constant throughout the upper water column, which may be the result of mixing due to large swell size often found in the Richards Bay area.

It is important to note that the values displayed in Table 2.5, were only collected when it was "suitable to launch". It may not entirely convey the real environmental conditions for that particular time of year.

The majority of humpback dolphin sightings per month occurred in water depths of 12.4 - 15.5 m (present study). Durham (1994a) recorded the majority of humpback dolphin sightings in a water depth of 15.7 m (± 5.4 m), while Karczmarski (1996a) and Karczmarski *et al.* (1998) found the majority of sightings at a depth of less than 15 m. Jefferson *et al.* (1993) furthermore stated that humpback dolphins were only observed within the 20 metres isobath, which suggests water depth is probably the main factor that limits the distribution of *Sousa chinensis* (present study).

Humpback dolphins were seen most frequently in the southern and harbour mouth regions of this study area and it most likely represents preferred areas. It seems that the effluent pipeline offers a suitable feeding area in the north, due to the amount of time they spent in this area while followed. The humpback dolphins apparently were attracted to the harbour mouth, areas *j1*, *j2* (that includes the southern part of the shark net installation) and *k2* (south breakwater) (Figure 2.2) to feed near the breakwater/piers (de la Mère 1999), probably since piers may act as artificial reefs (Karczmarski 1996b; Ross *et al.* 1994).

Humpback dolphins were mostly found approximately 150 to 400 m from the shoreline in the Algoa Bay area (Karczmarski 1996b) and Gaskin (1982) encountered them consistently close inshore, moving forwards and backwards along stretches of sandy shore with reef outcrops, on the South African coast. In contrast humpback dolphins were seen most often within two kilometres from the coastline (present study), which can be attributed to the nature of the Tugela Bank, where the 15 m isobath extends further offshore and can reach a width of nearly 8 km off Port Durnford (Durham 1994a) south of New Mouth.

In conclusion, it appears that the average group size recorded for the present study was larger than most other studies. No evidence for humpback dolphin preference for turbid water existed, whereas water depth seems to remain the most important factor determining humpback dolphin distribution.

Chapter 3

Humpback dolphin capture history in shark nets

Introduction

On the eastern coast of southern Africa, small cetaceans are being caught in gill nets permanently set at certain KZN beaches to protect bathers from shark attacks. The first nets were installed in Durban in 1952 and subsequently at other localities with private tenders servicing these nets until the late 1970s. Since the early 1980s the entire shark netting operation has been co-ordinated by the Natal Sharks Board (NSB). Information of dolphin captures only became accurate after this time (Peddemors 1993).

The net installations in KZN stretch from Mzamba in the south to Richards Bay in the north, at an average distance of 5.4 km apart (Durham 1994a) (Figure 3.1). In 1994 about 40 km of nets protected 45 bathing beaches along 326 km of coastline (Davis, Cliff and Dudley 1995). The entire shark net installation along the KZN coast (including Richards Bay) has caught more than 100 humpback dolphins since 1980. More than 70 of these humpback dolphins have been caught and retrieved from the Richards Bay shark nets (NSB capture data). Durham (1994a) found a decline in humpback dolphin sightings within the above mentioned area, with 74% of all humpback dolphin captures occurring in the four northern-most installations of the KZN shark nets.

In 1994, Durham (1994a) found that Richards Bay showed a higher density of humpback dolphins than any other locality along the KZN coast. He stated that if shark nets were responsible for depleting the humpback dolphin population along the KZN coast, the main reason for the high density in Richards Bay would be that the population has not (yet) dropped to levels apparent elsewhere since the nets in Richards Bay were

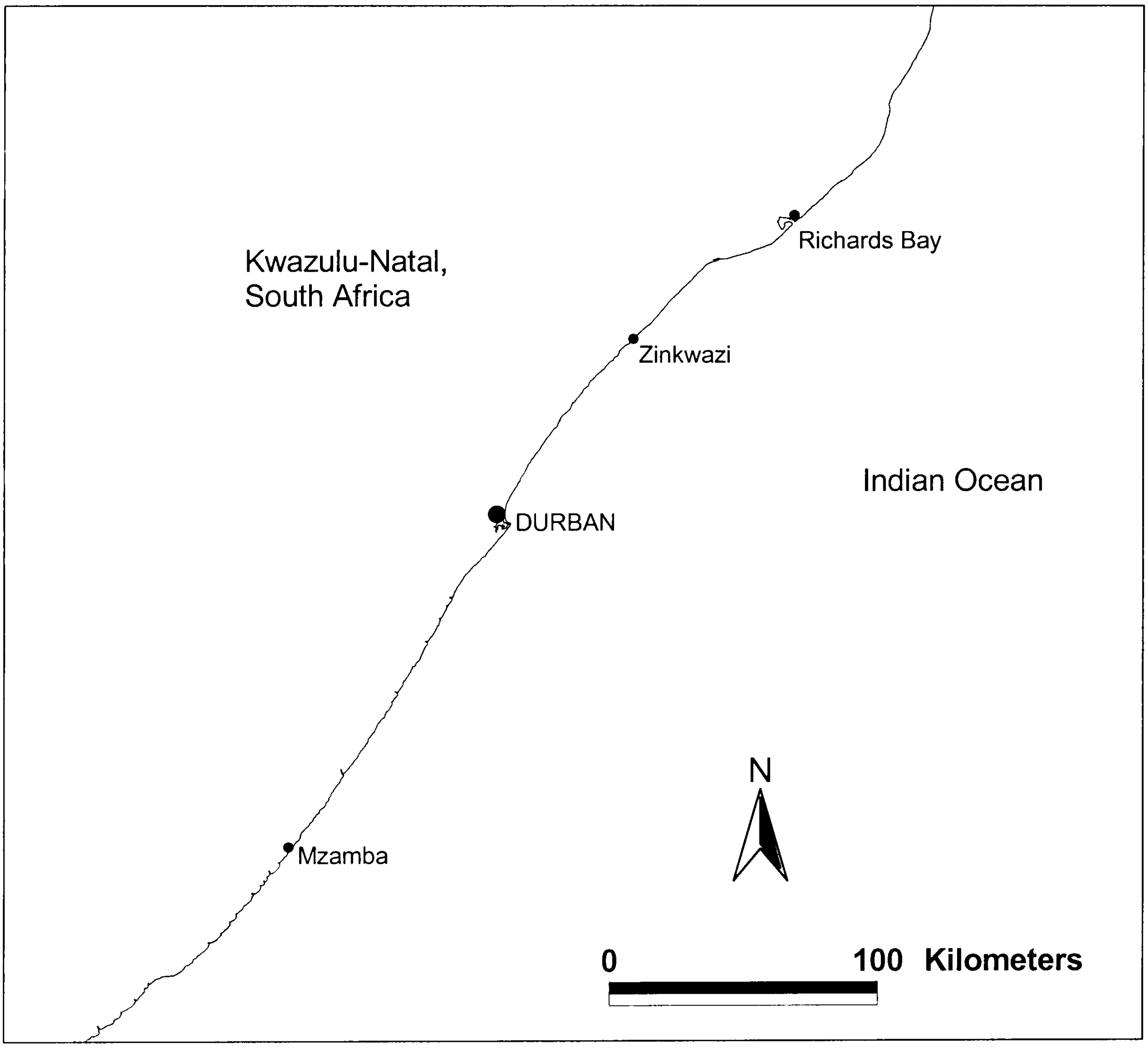


Figure 3.1. The shark net installations in KwaZulu-Natal, South Africa, stretch from Mzamba in the south to Richards Bay in the north.

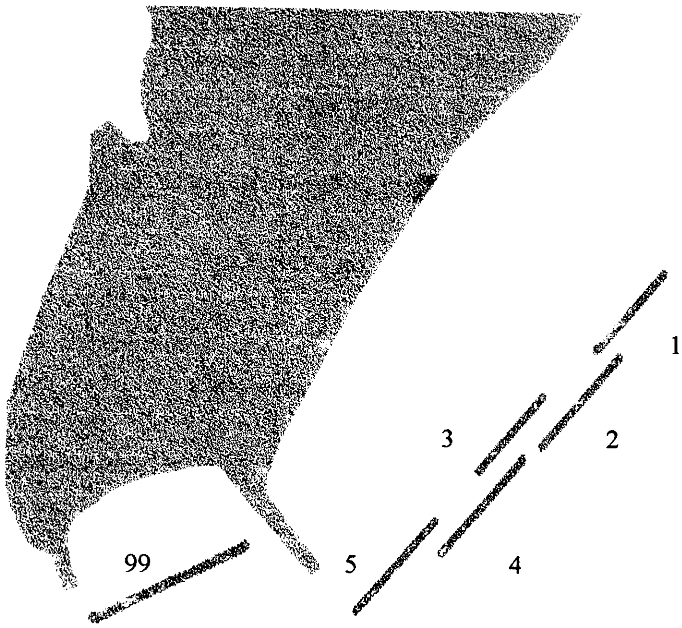
only installed in 1980. If this holds true, the KZN population is under pressure, seeing that since 1994, 15 dolphins have been caught in the Richards Bay installation alone, and during 1998, five dolphins were captured. This certainly implies that Richards Bay may represent a high capture area which may in the long run have an effect on the whole KZN population.

The capture data collected since the installation of the Richards Bay shark nets was obtained from the NSB. This chapter aims to investigate and analyse for any temporal pattern in the capture rates of humpback dolphins.

Materials and Methods

The nets are made up of 3 mm black and blue multi-filament nylon, with a mesh size of 25 cm. Each net is approximately 106 metres long and 6.3 m deep. The nets are placed parallel to the coastline in a water depth of approximately 12 m usually between 400 m and 800 m from the shore (Durham 1994a). Each net is fixed at each end by a set of anchors. At the top of each net are float buoys and the net is weighed down by lead sinkers at the bottom. The netting installation is set in two rows parallel to the shore so that the nets in the second row overlap the nets in the first row by about 20 metres (Davis *et al.* 1995).

Currently there are five double nets (two 106 metre nets linked) and one triple net (3 x 106 m) in Richards Bay (Figure 3.2). All nets are examined daily for caught animals at day break (weather permitting). Live captured animals are released (sharks are tagged and released), with dead animals dumped at sea when in a bad state of decay. Fresh captures are returned to shore and used for research purposes (Davis *et al.* 1995; Durham 1994a). Over the period of maintaining the installation, the number of nets installed varied (see Table 3.1). Capture data (from 1980-1998) consisting of the date, net number, location (position in the net), body length measured in the field, and the state of decay were received from the NSB and used for analyses.



Harbour mouth

Figure 3.2 Current configuration of the Richards Bay shark nets. Five double nets (two 106 metre nets linked) (numbered one to five) and one triple (3x106 m) net (net 99).

Table 3.1 Historical information of the number of nets and total combined lengths (in metre) of the Richards Bay installation (One net is approximately 106 metres).

Years	Net combination	Length for each year	Combined length for whole period
1980-1985	Seven double nets	1484	8904
1986-1990	Seven triple nets and one double net	2438	12190
1991-1997	Seven double nets and one triple net	1802	12614
1998	Five double nets and one triple net	1378	1378

Data analysis:

A Chi-square test (Williams 1993) as well as the Kolmogorov-Smirnov tests (Steyn, Smit, Du Toit, and Strasheim 1994) were used to analyse the historic capture data. The proportion of dolphins caught in relation to the combined length of installed nets for each year was calculated by combining the total length of nets for each year and dividing the total number of animals caught by the total length of nets. Further statistical analysis concerning any correlation between the number of dolphins caught in relation to the lengths of nets was accomplished by using a Pearson's linear regression (Zar 1984). Four different time categories, presented in Table 3.1, were used for the above analysis.

Results

A minimum of 72 dolphins have been caught since deployment of the Richards Bay shark nets in 1980. An average of 3.79 (S.D. ± 3.08) dolphins per year were caught throughout the 19 year period of installation. Monthly, an average of 0.32 (S.D. ± 0.76) dolphins were caught. The total number of captures per month collectively indicated a peak of 11 captures in June, July and October (Figure 3.3). Of the other months, March and April represented the lowest capture rate (2 individuals per month), with August collectively showing eight individuals caught since 1980. However, no significant difference in capture rates ($\chi^2 = 21.61$, df = 11, ns) between months was found.

A total of 34 females and 32 males were caught in the nets. Six dolphins were not sexed upon finding them in the nets. On analyses of differences in captures between males and females in terms of monthly temporal distribution, a peak in captures of males seems to exist for June (Figure 3.4). No significant difference (Kolmogorov-Smirnov = 0,1007 n = 11, ns) between male and female captures between months was evident. Further analysis yielded no significant difference ($\chi^2 < 17.59$, df = 11, ns) between monthly number of captures for males and females.

Thirteen dolphins were caught in the first year of installation, 1980 (Figure 3.5). The number of capture events, irrespective of the number of dolphins retrieved, is also

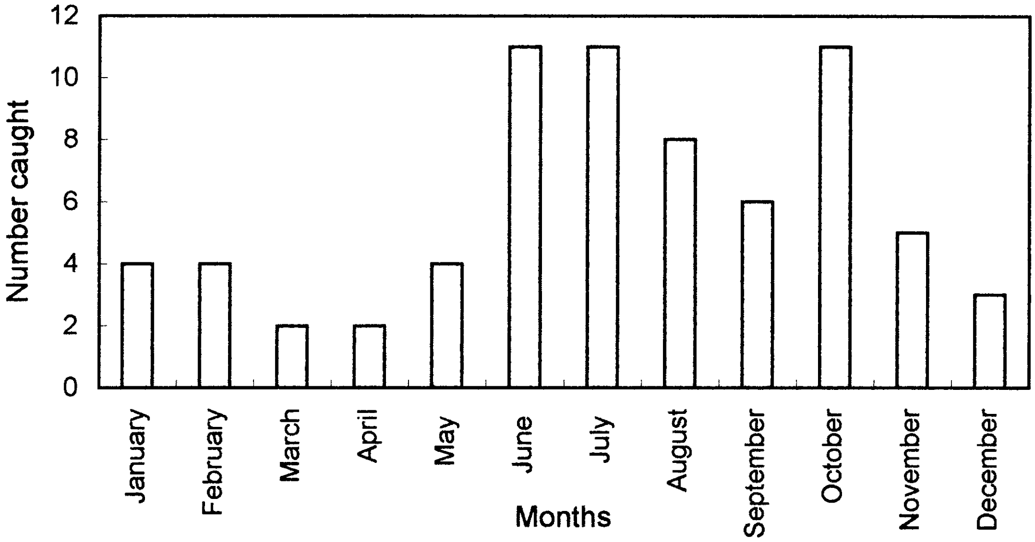


Figure 3.3 Combined monthly distribution of the number of humpback dolphins caught in the Richards Bay shark nets during the 1980-1998 period.

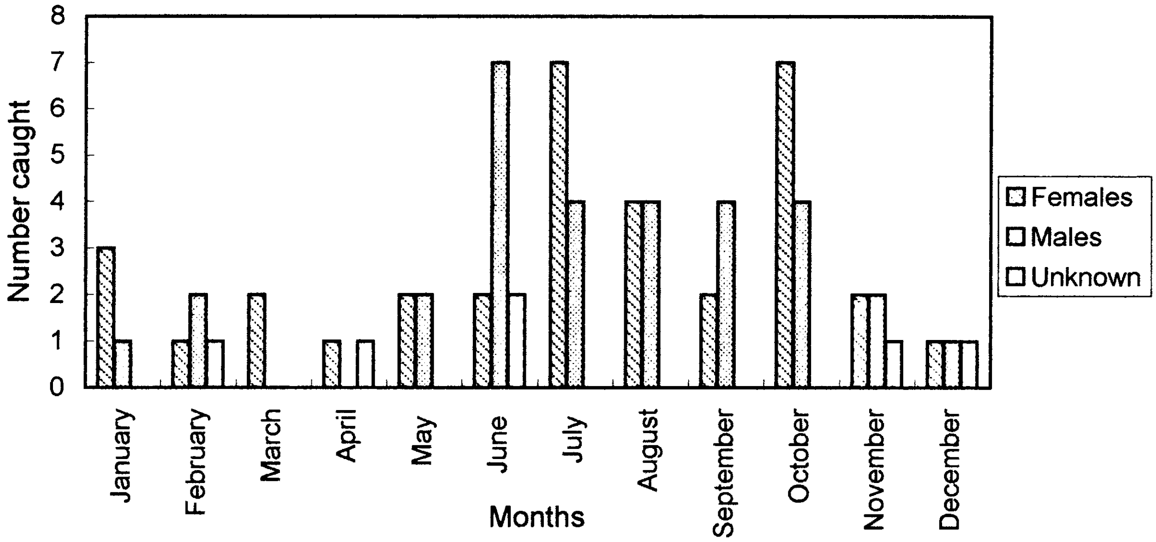


Figure 3.4 Monthly distribution of male, female and un-sexed humpback dolphin captures in the shark nets of Richards Bay.

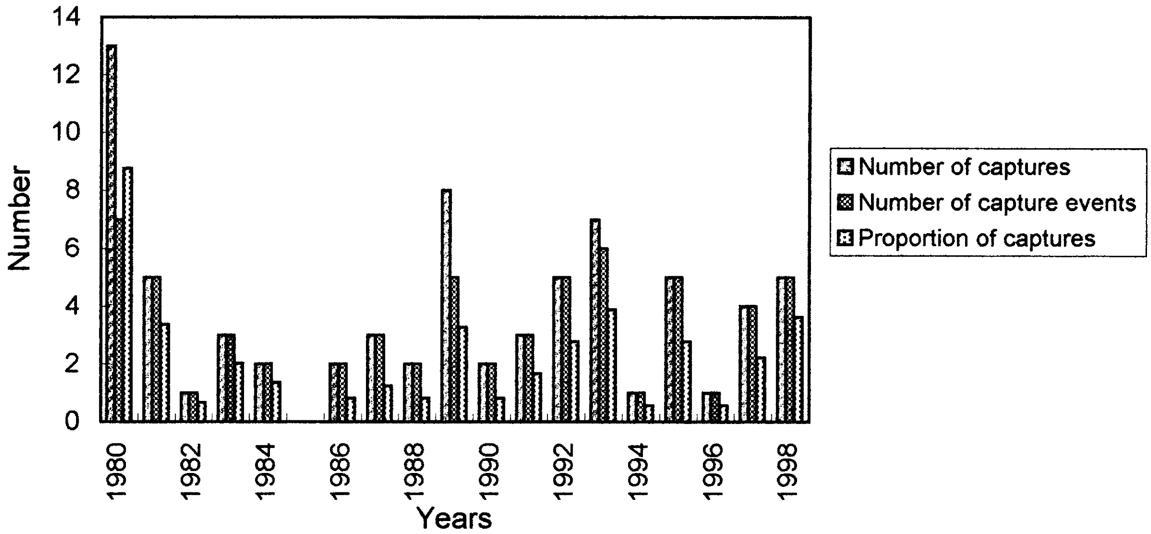


Figure 3.5 Number of humpback dolphins captured in the period 1980-1998. Included are the proportion of dolphins caught in relation with the total length of nets, as well as the actual number of capture events.

displayed in Figure 3.5. The second-most number of dolphins (n = 8 individuals) were caught in 1989. The number of dolphins caught each year differed significantly (χ^2 = 56.21, df = 18, p < 0.001). The proportion of dolphins caught in relation to the length of nets, did not significantly deviate from zero (Pearson's linear regression: y = - 0.0012 x + 6.116; r^2 = 0.656; ns). During 1985 (14 months from December 1984 to the beginning of 1986), no dolphins were retrieved from the Richards Bay installation.

On eight occasions throughout the 19 years, more than one dolphin was retrieved on the same day. Three female-male, one male-male, one unsexed-male, and two female-female pair captures and one triple female capture occurred throughout the period.

The body lengths (tip of mouth to the notch between tail flukes) of captured animals in Richards Bay varied between 1.52 metres and 2.85 metres with the average length of dolphins retrieved being 2.11 metres (S.D. ± 0.402). Males were on average 2.24 metres long (S.D. ± 0.29), with females being on average 2.1m (S.D. ± 0.31) long. The longest male caught was 2.85 metres and a female of 2.72 metres. Taking into account the cumulative figure of captures for the whole period, the linear trendline in lengths remained reasonably constant, with a slight decrease (y = -0.20x + 2459.9) over the study period (Figure 3.6).

The collective lengths for each length category (total captured, females and males) indicate that the majority (58 %) were shorter than 2.3 m long, with a peak in captures for the 2.2-2.3 m category (Figure 3.7). Significant differences existed in the distribution of certain lengths for males (χ^2 =29.13, df = 13, p < 0.05) and all the lengths combined (χ^2 =31.33, df = 14, p < 0.05), irrespective of sex. No significant difference was found in the analysis of female lengths for the different body length categories (χ^2 =18.75, df = 13, ns) (Figure 3.7).

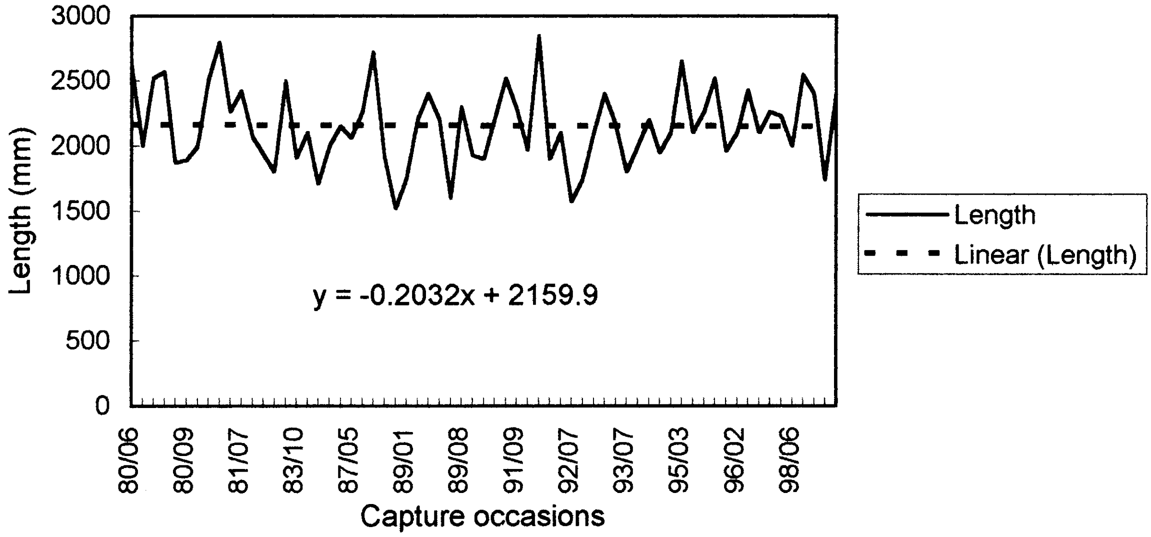


Figure 3.6 Distribution of body lengths of captured individuals for the duration of the installation.

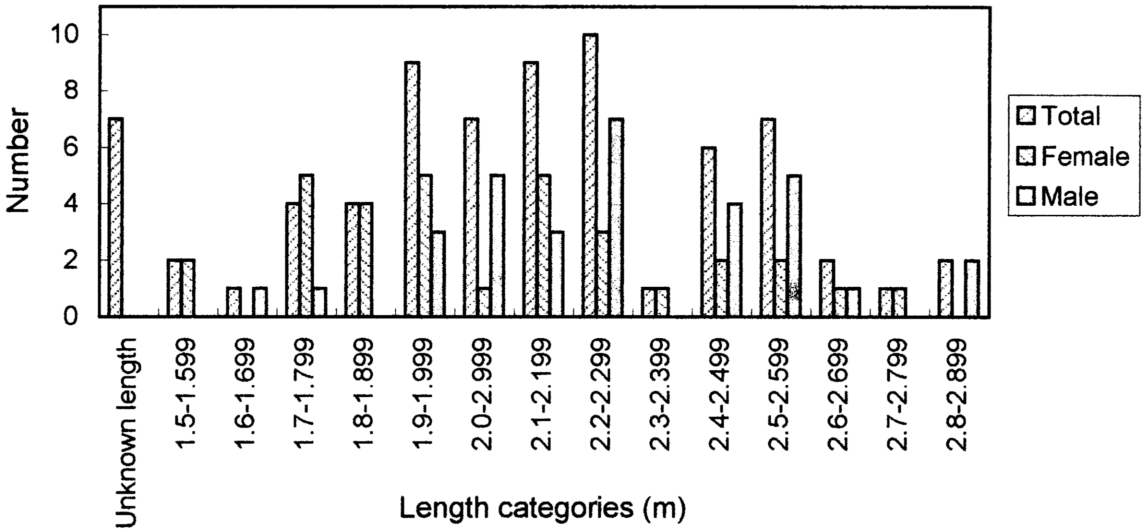


Figure 3.7 Categorised body length distribution for the total number of humpback dolphins, males and females caught in the Richards Bay shark nets.

Discussion

The majority of humpback dolphin captures (Figure 3.3) occurred between June and October which is similar to the findings of Cockcroft (1990) where the majority of captures occurred between autumn and spring. A study of the by-catch in the shark meshing programme in New South Wales (NSW), Australia, found a higher capture rate from May to November each year (i.e. autumn to spring), for porpoises and dolphins, with a lower capture rate from December to April (Krogh and Reid 1996). The similarity in findings between this study and that by Cockcroft (1990) implies that the capture trends are real and have been continuing for several years.

During June to August a proliferation of sightings occurred mostly in the harbour mouth and netted area (Chapter 5; Figure 5.1) which correlates with the increase in captures during these months (June, July and October) (Figure 3.3). It could indicate differences in seasonal utilisation and movement of humpback dolphins leading to an increase in the number of dolphins caught during the winter months within the Richards Bay shark net installation.

The present study exhibits a nearly equal proportion of males:females captured in contrast to Durham (1994a) who found a male-female sex ratio of 3:1 of captured animals at Richards Bay. Durham (1994a) stated that certain dispersal strategies of many mammal populations are often based on the movement of particular age or sex classes and that the unequal ratio of sub-adult males to females in the Richards Bay area may reflect a particular dispersal strategy. The present study found that the monthly distribution of male and female capture records was not significantly different from each other, as was the difference between the distribution of combined monthly captures for both sexes (Figure 3.4). Although the majority of dolphins caught in 1998 were males, the overall distribution in monthly captures for the different sexes remains non-significant. Furthermore Durham (1994a) speculated that the Richards Bay area may act as a nursery area. If this is the case the number of females captured in the shark nets would be greater than the number of males captured. Therefore, the dispersal strategy suggested by Durham (1994a) may not be supported when considering the equal sex ratio of captures in the present study.

The combined annual capture records varied significantly from 1980 to 1998 (Figure 3.5) and the high number of dolphins caught in the 1980 period could be due to the initial unfamiliarity of the dolphins to the installation. The 1985-1986 period where no captures were recorded, was not reflected in the result presented by Cockcroft (1990) perhaps because that study analysed the four northern-most beaches while the present study only considered Richards Bay. It could also be due to an incomplete data set. Analysis of the catch per unit effort suggests that the number of nets (total length) do not influence the number of dolphins caught in this particular installation. It seems that the number of dolphins frequenting the netted and surrounding area may be the primary factor affecting capture.

The unusual capture of more than one dolphin on a particular day can not be explained adequately. Taking into account that the nets were installed in 1980, unfamiliarity to the nets may be one of the reasons for the five pair captures during 1980. No clear patterns were found for the sex, length and dates of these simultaneous captures. The multiple captures did not coincide with any change in the number of nets in use (Table 3.1), nor any other known historical event. It is interesting to note that the years with the highest number of captures (1980 and 1989) (Figure 3.5), were also the years where the most multiple captures took place. The data suggests that there may be a behavioural explanation for multiple captures. Male-pair, as well as female-pair captures could be linked to social behaviour, perhaps play behaviour. Stomach content analysis (unavailable at the time of writing) may also show co-operative feeding that could have caused the multiple captures. Although insufficient length data for the five 1980 multiple captures restricted the analysis, no pattern was found that may indicate mother-calf linked captures.

The present study yielded a body length distribution between 1.5 m - 2.85 m for captures in the Richards Bay installation and does not seem to differ from other studies where the captured body lengths ranged between 1.6 m to 2.7 m (Cockcroft, 1990) and 1.05 m - 2.69 m (Durham 1994a). The similarity in the above mentioned findings suggests that no particular length category is likely to be caught.

Only two females were larger than 2.5 m, with the majority of captured females being smaller than 2.3 m, although no significance difference was evident in the distribution of lengths. In contrast to the present findings, Cockcroft (1990) only found males to be larger than 2.5 m in length. The difference in the distribution of categorised lengths, suggests that males of certain lengths are caught more often, although statistical analysis could not identify the particular length category. No clear indication whether the nets are size specific, is apparent.

Data from the present study indicate that individuals seen in the area of Richards Bay, exhibit varying levels of residency (Chapter 5). Some individuals have been observed in Richards Bay in 1991, 1992 and 1995 (Chapter 4) and it appears that some bottlenose dolphin populations exhibit site fidelity over several years (Peddemors 1995). Limited data suggests that the more "resident" humpback dolphins are females (Durham 1994a). Similarly Peddemors (1995) found that few female bottlenose dolphins are caught within the preferentially inhabited area and therefore the existence of preferred areas may be important in influencing capture. Most of the caught bottlenose dolphins were not previously photographed in the area of capture, suggesting that dolphins are captured outside their preferred areas where the layout of the shark nets was unfamiliar (Peddemors 1995).`

Humpback dolphins caught during 1998 were only seen on a few occasions, or never before, within the geo-spatial area of the present study. Only two ("SFW & CAP 9-22") of the five dolphins had distinct markings on their dorsal fins, which would have made photo-identification possible. The above mentioned dolphins were seen twice and three times respectively within the study area before capture (low residency indexes (RI), Chapter 5). Other individuals with high RI values were seen frequently within the netted area, with no capture. Therefore, the hypothesis of Peddemors (1995) might have important effects on the deployment of acoustic warning devices in shark nets. It may be that the unfamiliarity of the installation for dolphins entering the netted area lead to capture. Consideration as to the origins of the caught dolphins moreover needs to be made when considering the impact of the Richards Bay shark net installation on the humpback dolphin population.

Recent population estimates (Chapter 4) set the Richards Bay humpback dolphins at around 210 dolphins. Eight captures a year will affect the population, even though it is an open population (Chapter 4). The cause of capture seems most likely to be unfamiliarity with the shark nets, with possibly other factors, such as dispersal strategies and behaviour (see de la Mère 1999) also playing a role. Durham (1994a) suggested that dispersal strategies resulted in an unequal catch ratio regarding sexes and that males dispersed more widely (as is the case for most mammals (Snyder 1976)) while females tended to stay in more defined areas. The increase in sightings in the harbour area (Chapter 5), as well as a peak in captures, seem to suggest that the winter is the most likely time for dolphin captures although other peaks in monthly captures do not fully support this hypothesis.

In conclusion, a minimum of 72 humpback dolphins have been caught since 1980 in the Richards Bay shark nets. No clear pattern in the temporal catch data were evident on analysis. It seems that one of the main reasons of humpback dolphin capture may be due to initial unfamiliarity to the installation of dolphins entering the area.

Chapter 4

Population characteristics and photo-identification

Introduction

Early researchers distinguished aspects of behaviour and ecology to be enhanced through recognition of individuals. According to Würsig and Jefferson (1990) the casual identification of individual cetaceans has been occurring for a long time. The use of photographic techniques to identify individuals by their natural markings have been well-established (International Whaling Commission 1990). The recognition of individual animals can be used as a tool for obtaining a large variety of natural history information. For most dolphins and porpoises, the trailing edge of the dorsal fin, which tapers from anteriorly to posteriorly to a thin sheet of connective tissue, is the most identifiable feature (Würsig and Jefferson 1990). A well marked individual is one that can be recognised by a matrix of marks which in human-related terms, "form a distinctive face" for the individual (Würsig and Jefferson 1990). When only one or two simple identification features are used, one may accidentally identify similar looking animals, as the same individual. Therefore it is essential to use a combination of marks, scratches, nicks and tears in the dorsal fin for a more reliable identikit. Longevity and the variability of marks are of critical importance for compiling the identikit. There seems to be no hard-and-fast rule on how long marks on dolphins last, but some studies have shown that the dorsal fin markings do last for a considerable time (some up to 7 years; Bigg 1982); scratch marks on the body not lasting as long. Bigg (1982) found that marks on the dorsal fin of killer whales (*Orcinus orca*) remained essentially unchanged, but the shape of the injuries on a growing fin tends to elongate slightly and become more shallow with time.

Among delphinids, social organisation is best known in killer whales and bottlenose dolphins. Group structure and associations range from being stable in the killer whale to relatively fluid in most other dolphin species (Slooten, Dawson and Whitehead 1993). Humpback dolphins in the Eastern Cape (South Africa), appear to exhibit a highly fluid social structure with casual and short-term affiliations (Karczmarski and Cockcroft 1997). According to Saayman and Tayler (1979), humpback dolphins near Plettenberg Bay travelled and interacted with different companions in groups of unstable and variable composition.

Two population studies have been done on humpback dolphins to asses the impact of captures in shark nets and other detrimental factors affecting the already small populations on the coast of South Africa (Durham 1994a; Karczmarski 1996b), but it is essential to continuously monitor these small populations. Durham (1994a) stated that the determination of the status and ecological requirements of this little known species is of particular importance, as population depletion in conjunction with mass habitat destruction, usually go un-noticed and unchallenged. This chapter deals with the design to obtain an estimate of identified individuals, as well as with the investigation of the social structure for the Richards Bay population.

Material and methods

Photo-identification:

Photographs were taken, using a SLR camera (Nikon, with a 70-300 mm lens), of a dolphin's dorsal fin and hump when surfacing to breathe, as perpendicular to the body axis as possible. Appropriate annotation of the photo sequence was done every five minutes with the behavioural observations taken by de la Mère (1999). When commencing photographing at each dolphin school sighting, the film spool and starting frame was recorded. By taking a photograph of the coastline, it was possible to keep track of individuals and group associations after photographic development. Following recommendations by the International Whaling Commission (1994), several photographs of an individual were taken to ensure that a suitable photograph, or suite of photographs, was obtained. A combination of different colour slide films was used (100, 200 and 400 ASA) depending on availability. Developed films were compared qualitatively to determine suitable methodology for future studies.

Tracings of photographed fins were made from colour slides, after projection and enlargement using a BRAUN AG 7 slide projector. All dorsal fins were traced with the slide projector positioned four metres away from the tracing surface. These tracings were used for individual identification purposes and to compile an identikit. Only a selection of photographs of equal quality was used for identification purposes (Hammond 1986). The tracings were given a quality (Q) value (zero to five with zero = poor quality and five = excellent), based on image size, focus, light and angle of the dorsal fin as well as exposure of photograph (following Peddemors 1995). Only tracings with a Q value of three and above were used for photo-identification purposes. All photographs taken from the beginning of April to the end of October were used for identification and estimation purposes.

The dorsal fin tracings were sorted following Karczmarski and Cockcroft (1998):

1. Tracings were grouped according to the general shape of the dorsal fin: normal shape (sickle shaped), or irregular.

2. The number and nature of the notches on the body further categorised the tracings:

   1. On the leading edge of the dorsal fin,

   2. On the tip of the dorsal fin,

   3. On the trailing edge of the dorsal fin,

   4. Nicks and notches anterior to the dorsal fin,

   5. Notches and nicks posterior to the dorsal fin.

   6. The shape of the most prominent notch was used to further categorise tracings. Notches were grouped in "U", "V", "square", "irregularly ragged" or "other" in shape.

3. Scarring on the body was divided into four categories: a) Anterior to the dorsal fin, b) on the dorsal fin, c) below the dorsal fin, d) posterior to the dorsal fin.

4. The tracings were further divided using any prominent colour variations on the hump or surrounding areas.

All new tracings were compared with the tracings in the identification catalogue, to identify any matches. When tracings were not matched using the matrix, the whole catalogue was searched to eliminate duplication. Generally all visible markings on an individual were used for identification purposes. All individuals were catalogued with the data relevant to each sighting to create a photo-identikit. All humpback dolphins caught in shark nets along the KZN coast were photographed and traced and compared to tracings within the catalogue. The International Whaling Commission (1994) emphasises, that when working with catalogues for identification purposes, the catalogue should be reassessed periodically and that all of the characteristic markings should be included and not just the most pronounced feature.

Photographs taken during previous years (catalogue I - Durham 1994a; catalogue II - Natal Sharks Board collection), as well as opportunistic photographs taken by other researchers along the coast of KZN, were included in the catalogue to determine any long-term residency and movement patterns. Catalogue I consisted of the individuals (photographic slides) identified along the KZN coast during 1991 and 1992 by Durham (1994a), obtained courtesy of the Port Elizabeth Museum. Catalogue II consisted of photographic slides taken by personnel from the Natal Sharks Board.

A dorsal fin ratio (DFR) for each tracing, as described in Defran, Schultz and Weller (1990) was calculated. Karczmarski and Cockcroft (1998) used a modified DFR as one identification measure for humpback dolphins in Algoa Bay, South Africa. This modification was introduced to enable inclusion of individuals with only one prominent and useable nick/notch. The length/size of the notch was measured, and divided by the perpendicular distance from the top of the fin to the bottom of the notch (Peddemors 1995). The DFR was subsequently used in distinguishing individuals with only one nick/notch in the present study although Karczmarski and Cockcroft (1998) found the DFR application for humpback dolphins to be limited.

Nature and estimated size of the population:

The number of newly identified animals, distinguished over time, was used to plot a "rate of discovery" curve. The shape of the "rate of discovery" curve, and sighting frequencies of the individual humpback dolphins were used to determine the nature of the population ("open" or "closed").

Karczmarski and Cockcroft (1997) stressed that all population estimates used in their study were estimates of marked dolphins (usually adults). Estimated group sizes were subsequently used to determine the proportion of individuals identifiable (X) as mainly adults are identifiable when using photo-identification methods (juveniles and calves do not generally have markings (Durham 1994a)). Therefore the estimate for the total number of dolphins (i.e. both identifiable (traceable) and non-identifiable) in the group or population (P) can be determined, following Durham (1994a), from the number of photographically identifiable individuals (I) using the formula:

$$P = I/X$$

Where: P - Total number of dolphins sighted (both marked and unmarked)

I - Number of photographically identified individuals

X - Proportion of identifiable individuals in a group.

Association patterns:

Karczmarski and Cockcroft (1997) quantified association patterns of humpback dolphin individuals using a “Simple Ratio Association Index” or an “Association Index (AI)”

$$AI = J / (A + B) - J$$

Where: J – number of joint sightings of individuals A and B,

A – total number of sightings of individual A, and

B – total number of sightings of individual B.

This technique appears more accurate due to the nature of the collected data and was adopted for this study. Group consistency was used to calculate association indexes for different individuals rather than associations between individuals that were closer than 2 m to one another, as in Ballance (1990). Only individuals identified more than three times were used for the association index in the present study. An association index is defined so that they range between zero (two individuals never seen together) and one (1.0) (two individuals always seen together). The higher the value the greater the level of association (Bejder, Fletcher and Bräger 1998).

Data analysis:

The study period was divided into equal sets of sampling occasions. This facilitated the calculation of the population estimate since combining sampling occasions into larger sample units, the estimate becomes less biased and more accurate (Wells and Scott 1990). The Schnabel population estimate was calculated manually from the accumulated data (Pollock, Nichols, Brownie, and Hines 1990). A Jolly-Seber estimate of the population was attempted using the program JOLLY (1991 version).

Results

Photo-identification:

Approximately 3000 photographs were taken, resulting in nearly 700 tracings of identifiable dorsal fins, during the study period. Four-hundred ASA films yielded the best results producing sharp clear photographs of dorsal fins. Using a combination of dorsal fin outline (for tracing purposes), as well as colour variation of hump and dorsal fin area, films of 100 ASA proved inadequate. Due to circumstances most of the colour slides taken were 200 ASA which yielded satisfactory results.

One hundred and sixty one individuals traced were identifiable (possessing nicks and identifiable markings) with 59 individuals, being photographed on more than one occasion (Table 4.1). Since 76 % (X = 0.76) of the individuals in a group were identifiable, it suggests that 212 individuals (P = 161 / 0.76) were the total number of dolphins sighted.

Population estimate:

The number of newly identified individuals did not decrease with time, suggesting that the population sampled at Richards Bay appears to be an open population (Figure 4.1). sThe Jolly-Seber estimate resulted in substantial calculation errors. The Schnabel's estimate for the population in Richards Bay yielded 213 (± 42.72 at the 95% confidence level) individuals in the population.

Fourteen humpback dolphins were re-identified from the 96 identified individuals which were photographed along the KZN coast during the period 1991 to 1992 and were included in catalogue I. Of the 14 dolphins, only four individuals were sighted during 1991, in the Richards Bay area with three individuals being sighted in St. Lucia, Zinkwazi and Richards Bay areas during 1992 (Table 4.2). Four individuals were re-sighted within the Richards Bay area during consecutive years 1991 and 1992. Three

Table 4.1 Number of times identified individuals were sighted during study period.

Number of individuals	Number of times sighted
101	1
21	2
14	3
4	4
2	5
4	6
5	7
1	9
1	11
1	12
2	13
1	16
1	17
1	21
1	22

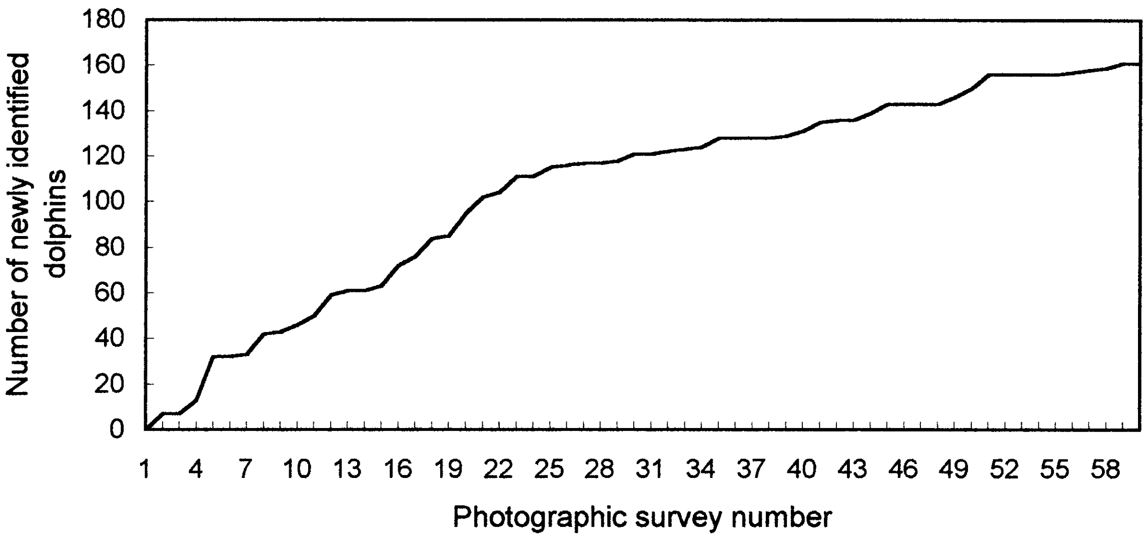


Figure 4.1 Discovery curve of newly identified individuals for the duration of the study, April to October 1998.

Table 4.2 Identified individuals from the present study which were also recognised from other catalogues accumulated in 1991, 1992 and 1995 (* indicate individuals present in both catalogues I and II).

Individuals	1991	1992	1995
t425a	3		
c-4-25-a		2	
e 4 25 d *		1	1
e bravo3	1	1	
e6161 *		1	1
l 7-13 a *		1	1
po423b		1	
po5-26a		1	
po85.	1		
t425a	1		
t519g	1	1	
t610c	1	2	
t610z	1		
t625alpha1	4	1	

individuals were identified from catalogue II, taken during 1995 in the Richards Bay area. These individuals were also identified from catalogue I and were photographed in 1992 (* Table 4.2).

Additionally a number of humpback dolphins were photographed in the Durban area on 15 June 1998 during another research project. One of these individuals was subsequently photographed and identified eight days later (1998/06/23) in the Richards Bay study area.

Associations:

Association index (hereafter AI) values are represented in a matrix (Table 4.3). Values ranged from zero to 0.54 for individuals seen together most of the time with an average AI value of 0.08 (S.D. ± 0.088). The highest value for the single regularly seen solitary animal was an AI of 0.19. No AIs were obtained for female/calf associations, as most of the calves did not possess identifiable features.

Discussion

Since the number of newly identified individuals did not decrease with time, it is proposed that the Richards Bay population is "open" in nature (Figure 4.1). Although Durham (1994a) also indicated that the Richards Bay humpback dolphin population may be open, he suggested that the population along the KZN coast may be considered as a closed population and calculated an estimate of 160.7 individuals (approximate 95% confidence limits 81 to 240) accordingly. Using all individuals identified during this study, an estimate for the Richards Bay area yielded a population of approximately 210 individuals, substantially higher than Durham's (1994a) estimate for the entire coast.

Table 4.3 Calculated association index values for identified individuals seen more than three times in the study area.

	Bottle-t4525a	c519a	e	e 4 25 d	e 5 26 z	e 518 a	e 617 alpha	e 619e	e bravo3.	e golf 2.	e18-5	e425b	e6161.	e86fox1.	po423b	po610alpha	quassi	t425a	t425b	t430bravo3.	T507A	t519g	t610br	t625alpha1.
Bottle-t4525a	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
c519a	0.10	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
e	0.05	0.27	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
e 4 25 d	0.13	0.04	0.00	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
e 5 26 z	0.18	0.13	0.05	0.13	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
e 518 a	0.14	0.03	0.00	0.00	0.04	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
e 617 alpha	0.13	0.00	0.00	0.13	0.13	0.00	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
e 619e	0.11	0.08	0.08	0.09	0.05	0.06	0.00	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
e bravo3.	0.06	0.14	0.00	0.13	0.06	0.00	0.14	0.10	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
e golf 2.	0.18	0.12	0.08	0.00	0.25	0.13	0.10	0.17	0.10	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
e18-5	0.06	0.18	0.33	0.00	0.00	0.00	0.00	0.09	0.13	0.09	o	o	o	o	o	o	o	o	o	o	o	o	o	o
e425b	0.12	0.13	0.08	0.10	0.00	0.06	0.11	0.00	0.11	0.18	0.10	o	o	o	o	o	o	o	o	o	o	o	o	o
e6161.	0.14	0.27	0.12	0.06	0.32	0.15	0.07	0.12	0.07	0.46	0.06	0.13	o	o	o	o	o	o	o	o	o	o	o	o
e86fox1.	0.33	0.00	0.00	0.00	0.05	0.00	0.10	0.08	0.00	0.08	0.00	0.00	0.06	o	o	o	o	o	o	o	o	o	o	o
po423b	0.06	0.04	0.10	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.29	0.00	0.00	0.00	o	o	o	o	o	o	o	o	o	o
po610alpha	0.06	0.04	0.18	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	o	o	o	o	o	o	o	o	o
quassi	0.07	0.19	0.04	0.10	0.15	0.04	0.05	0.04	0.11	0.14	0.10	0.05	0.21	0.09	0.00	0.00	o	o	o	o	o	o	o	o
t425a	0.13	0.54	0.21	0.04	0.03	0.06	0.00	0.07	0.04	0.12	0.13	0.12	0.13	0.00	0.08	0.08	0.15	o	o	o	o	o	o	o
t425b	0.06	0.13	0.08	0.22	0.36	0.00	0.11	0.08	0.25	0.08	0.00	0.09	0.13	0.00	0.00	0.00	0.10	0.12	o	o	o	o	o	o
t430bravo3.	0.00	0.04	0.18	0.00	0.12	0.06	0.11	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.11	0.20	0.00	0.12	0.00	o	o	o	o	o
T507A	0.00	0.03	0.07	0.08	0.05	0.25	0.08	0.14	0.00	0.14	0.00	0.00	0.05	0.07	0.00	0.07	0.04	0.03	0.15	0.15	o	o	o	o
t519g	0.05	0.12	0.27	0.00	0.11	0.06	0.10	0.00	0.00	0.17	0.20	0.08	0.00	0.00	0.00	0.18	0.04	0.07	0.08	0.08	0.14	o	o	o
t610br	0.00	0.00	0.00	0.13	0.06	0.00	0.00	0.10	0.00	0.10	0.00	0.00	0.14	0.10	0.00	0.00	0.00	0.04	0.00	0.11	0.08	0.10	o	o
t625alpha1.	0.07	0.54	0.21	0.00	0.07	0.04	0.05	0.05	0.18	0.10	0.24	0.05	0.17	0.00	0.11	0.10	0.18	0.31	0.10	0.10	0.04	0.15	0.00	o

The short duration of this study and a relatively low recapture rate resulted in substantial calculation errors when using the Jolly-Seber population estimate and inferred that a Schnabel estimate should be used to calculate a population estimate (Pollock, Nichols, Brownie, and Hines 1990). Other authors have also used this procedure when data was collected within one season (Hammond 1986). However, it is cautioned that using this method may not allow for random mixing and may subsequently result in an underestimation. Both Hammond (1986) and Durham (1994a) felt that the assumption that all individuals have an equal chance of being caught during each sample is usually violated. According to Wells and Scott (1990), one way to reduce the bias of unequal identification probabilities is to increase the sampling effort so that individuals with a low sighting probability would be more likely to be sampled. This method requires that marked dolphins are counted at most once during each sampling period regardless of the number of times they are actually sighted. Secondly, unmarked animals are also counted at most once during each sampling period, i.e., once they are sighted during the surveys, they become marked. However, this latter assumption implies that all individuals can be uniquely identified (Wells and Scott 1990). This assumption is violated for most sub-adult humpback dolphins. In an attempt to reduce bias, the sampling units used in the population estimate were subsequently divided into equal sized combinations of sampling occasions.

The high number of individuals seen once only (101 individuals; Table 4.1), coincides with the findings from Durham (1994a) that the population in the Richards Bay area is only a part of the larger population along the KZN coast and may form a sub-population. The continually increasing discovery curve supports this assumption. The continual discovery of new individuals in conjunction with some individuals exhibiting long distance movements along the coast, indicates that a large part of the sampled population does not constitute dolphins actually resident within the study area. The hypothesis for dolphin capture in shark nets suggests that dolphins are usually caught outside their "preferred" areas, or "home ranges", where they do not know the lay out of the net installation (Peddemors 1995). Peddemors (1995) indicated that preferred areas or home ranges play a role in bottlenose dolphin capture, but no evidence has previously been forthcoming for humpback dolphins. Data collected during this study imply that humpback dolphins with high residency indices were not captured in shark nets, while caught dolphins were "new" to the area (Chapter 5), supporting the hypothesis that knowledge of net lay out is important in minimising capture risk.

Seventy-four percent of all humpback dolphins are caught in the four northern-most shark net installations situated within the Tugela Bank region (Durham 1994a). Ninety percent of these catches occur in Richards Bay, with more than 70 humpback dolphins having been retrieved from these shark nets since 1980 (Chapter 3). The majority of the identified individuals (63 %) were only photographed once within the study area, again supporting the hypothesis that unfamiliarity may be one of the main factors contributing to the high humpback dolphin capture rate in the Richards Bay installation.

Two of the dolphins identified from catalogue I and II, were present in St. Lucia and Zinkwazi during previous periods of sampling. Additionally, one dolphin was seen in the Durban area at the beginning of July 1998 and in Richards Bay later that month, indicate substantial coastal movement ranging from approximately 50 to 120 km. In Algoa Bay, humpback dolphins also travel distances exceeding 110 km (Karczmarski 1996b; Karczmarski *et al.* 1998). Karczmarski *et al.* (1998) reports that the total long range movement of humpback dolphins in the Algoa Bay region remains unknown, and an extensive population range approximating a few hundred kilometres seems possible. In an analysis of the genetic diversity of humpback dolphins along the KZN coast, Smith (1990) suggested that humpback dolphins reside in definite home ranges, with limited genetic interaction and possibly limited physical interactions within the above mentioned population. However, this finding appears flawed considering the large-scale movement patterns found both in this study and that of Karczmarski *et al.* (1998).

A proportion of the individuals identified displayed "long term residency" during the study, while a large part were only seen once within the study area. Durham (1994b) speculated that females on the KZN coast were more resident and tended to remain around large river systems, while males and possibly sub-adults ranged from one river system to the other. The findings of Smith (1990), which suggests little or no annual or seasonal movement between observed resident areas of KZN humpback dolphins, may therefore be questioned, and it may be that the home range of the dolphins studied in this area ranges from St. Lucia in the north to Durban in the south, as indicated by the coastal movement of recognised individual. The animals used in the Richards Bay population estimate could therefore be a large proportion of the KZN population, which have been photo-identified within this region due to their seasonal movement patterns. This movement is most likely linked to the seasonal fluctuation in food resources associated with rainfall patterns. Increased rainfall during summer causes river lagoons to break their banks and release increased abundance of preferred humpback dolphin prey (Barros and Cockcroft 1991). This allows humpback dolphins to spread out during the summer with restricted ranges in winter areas around permanently open river mouths i.e. Richards Bay as suggested by Durham (1994a).

Associations:

Analysis of association indices (AI), yielded values between 0.0 and 0.54 (Table 4.3) suggesting low levels of associations between individuals. Only a few individuals were seen consistently in association with one another, most of them female-calf pairs. The highest AI value obtained for individual humpback dolphins within the Algoa Bay region (Karczmarski and Cockcroft 1997), was lower than the maximum value for the present study. In turn, the average value for the AIs from the present study is considerably lower than the 0.15 (S.D. ± 0.10) calculated by Karczmarski and Cockcroft (1997). These results suggest that the fluidity of associations within the Richards Bay humpback dolphin population (this study) is as low as for Algoa Bay (Karczmarski and Cockcroft 1997).

Only a few individuals scored high AI values (above 0.4). Many of these individuals scored the ten highest residency index values (Chapter 5; Table 5.1). It appears that the "resident" dolphins, seen during most of the follows, were also the individuals that associated with one another most of the time, all be it at relatively low level of associations. Similarly Slooten *et al.* (1993) found that the "resident" Hector's dolphin population in New Zealand, was characterised by relatively fluid associations, the associations lasting only for a few days.

Social structure estimates of humpback dolphins were severely hampered by irregular movements of groups of dolphins, also a difficulty in Algoa Bay (Karczmarski 1996b). Karczmarski (1996a) suggested that the societies of bottlenose dolphins and humpback dolphins off the South African coast are relatively fluid, with individual dolphins associating casually with a large number of other individuals. Such a "fission-fusion" society has previously been reported for bottlenose dolphins in Shark Bay, Western Australia (Connor, Smolker and Richards 1992). The lack of consistency within humpback dolphin group memberships seems to be the general pattern, with the only long term persistent membership being mother-calf associations, with calculated AI values equal to one (Karczmarski and Cockcroft 1997). Such high levels of associations were usually only apparent in Algoa Bay during the first three years of the calf's life (Karczmarski 1996b).

Saayman and Tayler (1979) stated that the fluid nature of the humpback dolphin's social groupings indicate perhaps, like the society of chimpanzees, that unseen societal bonds are so strong that they can survive long periods of division. Alternatively, Gaskin (1982) noted that no such intricate groupings were noticed with bottlenose dolphin groups and simply suggested that societal bonds are loose, and that animals wander in and out of areas, or move out permanently to seek new areas, due to the fact that dolphin societies do not function as a primate society. The latter is supported by findings from the present study as well as that from Durham (1994a).

Finally, the estimated humpback dolphin population size of 213 individual may form a large part of the KZN population. Some identified individuals exhibited extensive movement along the KZN coast. Low levels of social affiliation was recorded for the humpback dolphins in the present study. As the majority of the identified individuals (63 %) were only photographed once within the Richards Bay study area, unfamiliarity may be one of the main factors contributing to the high humpback dolphin capture rate in the Richards Bay installation.

Chapter 5

Site fidelity, home ranges and the effects of acoustic warning devices

Introduction

Certain humpback dolphins were identified as part of a school that habitually ranged throughout the Plettenberg Bay and adjacent areas, South Africa, throughout the year (Saayman and Tayler 1979). In contrast, humpback dolphins in Algoa Bay displayed varying but generally low levels of site fidelity (Karczmarski 1996b). Little is known of the site fidelity of the humpback dolphin found along the KZN coast, but Durham (1994a) presented evidence of a "preferred area" on the northern part of the Tugela Bank (KZN).

According to Peddemors (1995) bottlenose dolphin schools appear to reside in defined home ranges or preferred areas of between 33 to 42 km long-shore, along the KZN coast. Considerable seasonal variation in the bottlenose dolphin population occurs inshore with increased abundance during the austral winter and spring months (Peddemors 1995). It appears that some bottlenose dolphins exhibit site fidelity over several years and these animals usually represented more "resident" females. Most identifiable bottlenose dolphins caught in the shark nets during the study of Peddemors (1995) were not previously photographed in the area where the capture occurred. The number of dolphins caught within their "home ranges" were proportionately small and this would suggest that dolphins usually are caught outside their "preferred" areas or "home ranges", in places where they do not know the lay out of the netting installation.

Reduction of incidental captures would probably be most effective if the dolphin's attention can be focused onto the nets. It has been postulated that active acoustic warning devices would be most effective but dolphin reactions need to be ascertained before costly experiments can be undertaken. Active acoustic deterrent devices (pingers) were therefore introduced during June 1998, into the Richards Bay shark net installation, in an effort to reduce the rate of captures of the humpback dolphins in the shark nets. Investigating site fidelity and home ranges could provide vital insight into the reasons for the remarkable high capture rate of humpback dolphins in the Richards Bay shark nets (Durham 1994a) and clarify the effects that acoustic warning devices would have on the humpback dolphins.

Materials and Methods

Karczmarski and Cockcroft (1997) calculated Residency Indexes (RI_1) for individuals which related the total number of sightings of an individual (S) to the number of months in which the particular individual was seen (M):

$$RI_1 = S \times M / 100 \quad \text{(1)}$$

Adapted RI indexes were calculated

$$RI_2 = T \times R / Z \quad \text{(2)}$$

where: T = Number of sightings for a particular individuals divided by the total number of dolphin sightings,

R = The number of months an individual was seen divided by the duration of the study in months,

Z = The highest T x R value for an individual in the study.

Equation (2) represent the RI values for individuals sighted on more than one occasion. The RI_2 value represents a relative measure. Calculated RI_2 values are assessed relative to the highest scoring individual (Z). Thus the most resident individual has a RI_2 value of one.

Acoustic warning devices (pingers - see introductory chapter), were introduced into two nets (net 5 and net 99) within the Richards Bay shark net installation (Figure 3.2) on 22 June 1998. The experiment had three states of deployment, i.e. pingers, dummies (black plastic pipes identical to the pingers) and no deployment (first three months of the study). The state of the deployment, and to which net the pingers would be installed, was decided randomly through flipping a coin. The state of the experiment changed every seven days (weather permitting). The pinger experiment was monitored by the Natal

Sharks Board of Richards Bay to ensure that observers were not aware of the state of the experiment so as to reduce bias. When dolphins were followed into the harbour mouth/netted area, photographs were taken of the individuals closest to the nets for identification purposes.

The study area was divided into one kilometre square units (Figure 2.2) and a matrix of the study area was constructed to accommodate easier analysis of site fidelity. Individuals sighted more than three times were used to establish individual site fidelity. Blocks *d-h* were classified as the northern region of the study area, with *i-k* as the harbour mouth area and *l-p* the southern region of the area (See Figure 2.2). The shark nets of Richards Bay were situated within blocks *j1* and *i1*. The south breakwater was in block *j2* (Figure 2.2).

Data analysis:

Due to the limited data set, comparison amongst the three different stages of the pinger experiment could not be run. The number of sightings per square were categorised as one to three, four to seven and eight to eleven times to construct Figures 5.1 and 5.2

Results

The calculated RI values are presented in Table 5.1. The RI_1 values calculated for the different individuals ranged between 0.02 and 1.32 and the modified RI_2 values ranged between 0.02 and 1.00.

Table 5.1 Calculated residency indices (RI_1 and RI_2) for individually identified humpback dolphins sighted on more than two occasions. Included in the table is the different components for the RI_1 index.

Individuals	M	S	RI_1	RI_2
423A	1	2	0.02	0.02
abs1	1	2	0.02	0.02
alpha	1	2	0.02	0.02
e 18-5 c	1	2	0.02	0.02
e 4-25 kilo	1	2	0.02	0.02
noone	1	2	0.02	0.02
po kilo1	1	2	0.02	0.02
po6-3 alpha	1	2	0.02	0.02
sfw	1	2	0.02	0.02
cap9-22	1	3	0.03	0.02
egenuis1.	1	3	0.03	0.02
t519charly1.	1	3	0.03	0.02
A 5-6	2	2	0.04	0.03
ct814a	2	2	0.04	0.03
e golf 5	2	2	0.04	0.03
e golf 6	2	2	0.04	0.03
e406a	2	2	0.04	0.03
e425e	2	2	0.04	0.03
india8	2	2	0.04	0.03
knobie	2	2	0.04	0.03
po85.	2	2	0.04	0.03
t430d	2	2	0.04	0.03
t507alpha	2	2	0.04	0.03
t521a	2	2	0.04	0.03
a610beta(tp)	2	3	0.06	0.05
e 5-26alpha	2	3	0.06	0.05
e425x	2	3	0.06	0.05
e66g	2	3	0.06	0.05
e727echo1.	2	3	0.06	0.05
l 7-13 a	2	3	0.06	0.05
t430t	2	3	0.06	0.05
po423b	2	4	0.08	0.06
e507ch	3	3	0.09	0.07
po5-26a	3	3	0.09	0.07
t425c	3	3	0.09	0.07
t531v	3	3	0.09	0.07
e18-5.	2	5	0.10	0.08
e425b	2	6	0.12	0.09
po610alpha	2	6	0.12	0.09
t610br	3	4	0.12	0.09
e 4 25 d	3	5	0.15	0.11
e 617 alpha	4	4	0.16	0.12

Table 5.1 continued

Individuals	M	S	RI_1	RI_2
e bravo3.	4	4	0.16	0.12
t425b	3	6	0.18	0.14
e86fox1.	3	7	0.21	0.16
t430bravo3.	4	6	0.24	0.18
e	4	7	0.28	0.21
e 619e	4	7	0.28	0.21
e golf 2.	4	7	0.28	0.21
t519g	5	7	0.35	0.27
T507A	5	9	0.45	0.34
Bottle-t525a	5	13	0.65	0.49
e 5 26 z	5	13	0.65	0.49
e6161.	6	12	0.72	0.55
e 518 a	7	11	0.77	0.58
t625alpha1.	7	16	1.12	0.85
quassi	7	17	1.19	0.90
c519a	6	21	1.26	0.95
t425a	6	22	1.32	1.00

Table 5.2 represents the pinger experimental details, with the date, sex and net number for captured animals retrieved from the nets. Three of the five humpback dolphins were caught while the pinger experiment was underway, on all occasions with a set of dummies in the installation. Only two dolphins were photographed within the study area before their capture (SFW and CAP 9-22), with "CAP 9-22" being captured during the pinger experiment. Both "SFW" and "CAP 9-22" scored RI values of 0.02 respectively (Table 5.1). Both individuals were only seen in one month, twice and three times respectively, before being caught.

Table 5.3 details the 17 occasions that humpback dolphins were followed into the harbour mouth and netted area, including the estimated distances from the nets. On three different occasions the dolphin groups consisted of adults and juveniles and/or calves. During some follows individual dolphins were sighted within a hundred metres of nets with active pingers (see *; Table 5.3) as well as those without any active pingers.

Only three individuals were sighted during the whole study period (Table 5.4). Interestingly, the individual ("t 4 25 a") sighted on most of the launches, was only sighted during six months of the study period. Several animals were only seen two months in a row, while other individuals were photographed during one month and sighted again two months later. Other individuals displayed varying lengths of occupancy for the study area.

Most of the monthly follows (Figure 5.1) took place close to shore (rows one and two) and on some occasions (July and October) dolphins were followed further offshore (rows 5 and 6). During August and September no northerly follows (columns *d* - *h*) took place.

Varying patterns of utilisation of the different squares of the matrix were evident for each of 23 individuals (Figure 5.2). Seven individuals were not photographed in the vicinity of the netted area (*j1* and *i1*) or the harbour.

Table 5.2 Pinger experiment information with dolphin capture information for 1998 (date of capture, sex and location).

Date	Net	State of pinger	Retrieval date	Sex	Net
No experiment	-	-	4th of July 98	Male	99
No experiment	-	-	18th of July 98	Male	99
22 June-28 June	99	On			
29 June-5 July	99	On			
6 July-12 July	5	On			
13 July-19 July	99	Off			
20 July-26 July	5	Off			
27 July-2 August	5	On			
3 August-9 August	99	Off			
10 August-16 August	99	On			
17 August-23 August	5	Off	24th of August 98	Male	99
24 August-30 August	99	Off	31st of August 98	Female	5
31 August-6 September	99	On			
7 September-13 September	5	On			
14 September-20 September	5	Off	22nd of September 98	Male	5
22 September-27 September	99	Off			
28 September-4 October	5	On			
5 October-11 October	99	On			
12 October-20 October	5	Off			
21 October-26 October	5	On			
27 October-1 November	99	Off			

Table 5.3 Occasions when humpback dolphins were followed within the vicinity of the netted area. Group size, identified individuals, net number and distance from particular net are also listed (* indicate net with active pingers).

Date of dolphin follow within the netted area	Group size	ID	Net	Distance from net (m)
98/05/06	3		4 & 5 2 & 4	
98/05/18	4	2 Mother-calf pairs	5	
98/05/25	5	t-425a	Harbour mouth	
98/06/03	10		5	100
98/06/15	4	t-425a	5 99	50 70
98/06/19	6		4	50
98/06/20			3 1	100 20-40
98/07/20	4-7		2 4	100 70-100
98/07/30	9	c 5-19a	5* 99	100 150
98/08/13	4		5 99 *	60-70 60-70
98/08/15	6	Quassi , e526z	5 99*	100 200
98/08/20	1	Quassi	Harbour mouth	
98/09/15	6	c5-19a, Jr., t-425a	5 1+3	30 50
98/09/22	2	e86fox1, t-525a	5	50
98/09/23	2	e86fox1, t-525a	5	50
98/09/24	2	e86fox1, t-525a	5	30
98/10/23	5	c5-19a, Jr., t-425a	5*	20-50

Table 5.4 Monthly sightings for identified individuals sighted more than twice during the study period.

Individuals	April	May	June	July	August	September	October	Total number of months seen
po85.					1		1	2
e golf 6					1		1	2
ct814a					1	1		2
e86fox1.					1	1	1	3
e golf 5				1	1			2
l 7-13 a				1	1			2
po610alpha				1	1			2
india8			1			1		2
t610br			1			1	1	3
a610beta(tp)			1		1			2
e 619e			1		1	1	1	4
e 5 26 z			1	1	1	1	1	5
t507alpha		1			1			2
t531v		1			1	1		3
e golf 2.		1			1	1	1	4
e727echo1		1		1				2
e507ch		1		1	1			3
e66g		1	1					2
e18-5		1	1					2
e 5-26alpha		1	1					2
t521a		1	1					2
A 5-6		1	1					2
t 525 a		1	1		1	1	1	5
po5-26a		1	1	1				3
e		1	1	1	1			4
t519g		1	1	1	1	1		5
c519a		1	1	1	1	1	1	6
e6161.		1	1	1	1	1	1	6
e425x	1					1		2
t425c	1			1	1			3
e425e	1		1					2
po423b	1		1					2
e 4 25 d	1		1			1		3
t425b	1		1		1			3
e406a	1	1						2
e425b	1	1						2
t430t	1	1						2

Table 5.4 continued

Individuals	April	May	June	July	August	September	October	Total number of months seen
t430d	1	1						2
knobie	1	1						2
e bravo3.	1	1		1	1			4
T507A	1	1		1	1	1		5
e 617 alpha	1	1	1		1			4
t430bravo	1	1	1	1				4
t425a	1	1	1	1	1		1	6
e 518 a	1	1	1	1	1	1	1	7
quassi	1	1	1	1	1	1	1	7
t625alpha	1	1	1	1	1	1	1	7

a) **April**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

b) **May**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

c) **June**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

d) **July**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

e) **August**

New mouth * | Harbour mouth (ha) | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

f) **September**

New mouth * | Harbour mouth (ha) | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

g) **October**

New mouth * | Harbour mouth (ha) | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

Figure 5.1 a) - g) Matrix displaying monthly distribution of humpback dolphin sightings

Discussion

The original RI_1 from Karczmarski and Cockcroft (1997) was adapted to determine a better representation of observed residency in the study area (RI_2). The RI_1 values obtained for the present study were smaller (maximum $RI_1 = 1.32$) than for Karczmarski and Cockcroft's (1997) study where the index reached its maximum of 4.25 for the most frequently seen dolphin. This is due to the difference in duration of both studies as well as the number of resightings of individuals. It is important to note that both RI_1 as well as RI_2 are relative measures of an individual's residency to an area and not a absolute value.

Humpback dolphin follows within the harbour and harbour mouth occurred primarily from June to August (Figure 5.1), the period which coincided with the dolphin captures of 1998 in the Richards Bay installation. The distribution patterns of humpback dolphins during the winter months may therefore contribute to the peaks in by-catch of dolphins as described in Chapter 3. Several of the individuals with high RIs (Table 5.1) were frequently observed within the harbour area (Figure 5.2) while other individuals which were caught in the shark nets, had low or no RI values. Similarly Peddemors (1995) indicated that preferred areas or home ranges play a role in capture when the bottlenose dolphin ventured from it.

The repeated sightings (high RIs) of individuals indicate a preference for particular areas (Figure 5.2). Some individuals did not venture close to the netted area, while others were never observed in the northern part of the study area. Humpback dolphins in the Algoa Bay area displayed varying degrees of residency and fidelity (Karczmarski 1996b). Furthermore, it was found that the low overall level of site fidelity in Algoa Bay was likely to be a function of prey availability. Due to the nature of the exposed coastline of the Eastern Cape, prey resources in any one area could be restricted and in areas where prey densities are high, site fidelity may be greater (Karczmarski and Cockcroft 1997). This might be the case for the Richards Bay area, as the harbour mouth represents the opening to a large estuarine system which acts as a nursery and breeding ground for fish and the two breakwaters may serve as artificial reefs.

Non-resident dolphins are forced by limited food resources to forage over large areas (Karczmarski 1996b). Another hypothesis states that females were more resident in certain areas (large river systems), while males and possibly sub-adults moved from one river system to the other (Durham 1994a). Since the majority of humpback dolphins (63%; Chapter 4) were only sighted and photographed once within the Richards Bay area, perhaps one or both of the above mentioned arguments explain the movement of individuals through Richards Bay. On the other hand, the large scale movement and fluctuating site fidelity, observed on the KZN coast (Durham 1994a; Chapter 4) may not only be linked with insufficient food resources as proposed by Karczmarski (1996b). During the summer months (increased rainfall), some groups of dolphins move away from the "resident" Tugela Bank region (Durham 1994b). Similarly Barros and Wells (1998) found bottlenose dolphins of Florida to inhabit year-round home ranges with differential use of habitats. Therefore it is suggested that a combination of fluctuating resources and environmental conditions affect the site fidelity and movement patterns of humpback dolphins. Increased food resources during summer months might generate a widespread distribution of humpback dolphins throughout KZN. As increased rainfall in summer causes river lagoons to break their banks and release increased abundance of estuarine-associated fish into the marine environment. This increased abundance of preferred humpback dolphin prey (Barros and Cockcroft 1991) allows the humpback dolphins to spread out during the summer. In particular areas, such as Richards Bay, some dolphins remain ("resident individuals"), due to the constraints of pregnancy or lactation (Durham 1994a). With the onset of winter, the distribution of the resources decline and result in an influx of dolphins ("non-residents") into the more "preferred areas" (i.e. Richards Bay; as proposed by Durham (1994a)).

A home range is described as the area around the established home which is traversed by the animal in its normal activities of food gathering, mating and caring for the young (Durham 1994a). Hansen (1990) found for some bottlenose dolphins that the permanent home range of some individuals form part of the seasonal home range of other individuals. According to Durham (1994a) it could be inferred that the home range of humpback dolphins may be limited to areas surrounding each river system, and the infrequent movement between ranges represents wanderings or exploratory sallies. It could also be that the Tugela Bank, with estuaries or river mouths, form focal points, or core areas. Considering the observed site fidelity and home ranges in this study (Tables

5.1 and 5.4), it seems that the Richards Bay area is for some individuals a "core area" or "preferred area" while others individuals just pass through.

Durham (1994a) found that females in KZN tended to display generally higher degrees of site fidelity than males, but did not link it to the reproductive stage. Wells and Scott (1990) found that female bottlenose dolphins showed higher degrees of site fidelity than males in Sarasota. Most of the individual bottlenose dolphins were resident throughout the year with the exception of occasional absences of some adult males. Groups of females used portions of the study area on a regular basis, but ranged on occasions throughout the area and inter-mingled with other female groups (Wells and Scott 1990). Calves of both sexes remained in the area until they reached sexual maturity and for a longer duration. Males started to move further afield as they matured, seemingly travelling from one female band to the other (Wells and Scott 1990). It thus seems that the hypothesis formulated by Durham (1994a) could be true and that the high site fidelity displayed by humpback dolphin females is not only related to the reproductive cycle of females as proposed by Karczmarski and Cockcroft (1997).

It is still unknown whether nets with active pingers catch fewer porpoises (Dawson, Read, and Slooten 1998; Koschinski and Culik 1997; Kraus *et al.* 1997). It is suggested that acoustic alarms could reduce by-catch of cetaceans, if an animal became entangled because it was unaware of the nets' presence (Dawson *et al.* 1998). Therefore a system of alarms (acoustic warning devices) could work if (a) the animal learns to relate the sound with the danger of the net, and hence perceives it as indicating danger, (b) echolocation was encouraged, thereby making detection of the net more likely, and/ or (c) the sound in itself were aversive (Dawson *et al.* 1998). Since humpback dolphins were seen in the vicinity (20 – 200 m; Table 5.3) of nets containing active pingers, the effectivity of pingers as an aversive device is placed in doubt. However, the pingers used during the experiment may still act as a warning device through focusing the dolphin's attention on the net with the pingers, and does not necessarily require chasing the dolphin away from the area. It still remains unclear whether these pingers resulted in an encouragement of echolocation.

Identified individuals frequented the netted areas with and without pingers in place (Table 5.3). Even though three dolphins were caught in the shark nets during the pinger experiment, no final conclusion could be made with regard to the efficacy of the pingers, as all three captures took place during non-active pinger (dummies) periods. Any affect, if at all, will only be noticed over a longer period of pinger deployment. Humpback dolphins were followed on numerous occasions in the netted area with pingers (four times) and without pingers (13 times). Dawson *et al.* (1998) emphasised that the results obtained by Kraus *et al.* (1997) may not apply to other species, since the PICE© was developed to be a porpoise (*Phocoena phocoena*) deterrent, based on the acoustically aversive mechanism developed by Loughborough University, United Kingdom. It is therefore essential to acquire a better understanding of the sensory capabilities of humpback dolphins. Dawson *et al.* (1998) speculates that habituation to pingers may in the long run effect the "resident" dolphins. However it seems that familiarity of an area appears to be one of the most important factor effecting humpback dolphin captures (low residency indexes for captured dolphins, (Table 5.1)). If this hypothesis of unfamiliarity is true, individuals "that are most likely to be caught" in the nets with pingers will be warned off, without the problem of habituation.

No suckling calves and very few young humpback dolphins have been caught in the nets. Cockcroft (1990) states that females, young dolphins and lactating females do not frequent the inshore areas. Although very low numbers of young humpback dolphins have been caught in the Richards Bay nets, they do frequent the netted area, contradicting the above mentioned author's speculation, as to their low capture rate. One female (c5-19a) with a calf was seen on numerous occasions within the harbour mouth. On 17 occasions, groups of humpback dolphins, with calves or juveniles, were followed in close vicinity of the shark nets in Richards Bay (Table 5.2). Furthermore, a group of bottlenose dolphins with a small calf were seen swimming, in July, in close approximation (± 10 m) to the Richards Bay installation without entanglement. Therefore it still remains unknown why small calves and juveniles under the length of 1.5 m are not being caught even if they frequent netted areas (Chapter 3).

Humpback dolphins frequent the Richards Bay harbour mouth and were even followed into the harbour during the present study. Such behaviour is not unusual as Durham (1994b) and V. Peddemors (1999) report similar movements. In contrast, open stretches of coastline, sandy shores and areas of extensive human activity were used infrequently in Algoa Bay (Karczmarski *et al.* 1998). Jefferson and Leatherwood (1997) found that humpback dolphins were often seen feeding behind fishing vessels. Richards

Bay harbour first became operative in 1976 (Lord and Geldenhuys 1986) and is still being developed. Most humpback dolphin sightings were in areas of extensive human use (dredging - especially near the south breakwater in *j2* and *k2*, shipping, ski-boating and angling). These dolphins may therefore be exposed to severe noise and chemical pollution which may add to the increased effects of the already high concentration of organo-chlorine pollution found in the humpback dolphins (Cockcroft unpublished data).

In conclusion, humpback dolphins studied in the Richards Bay area display differences in site fidelity and have distinct levels of residency to the area, affected by various unknown factors. The fluctuation of residency may be directly involved in captures in the shark nets. Collected data from the acoustic warning devices remain inconclusive.

t425a

New mouth — Harbour mouth — Light house

*						ha					*	
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	h3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

c519a

New mouth — Harbour mouth — Light house

*						ha					*	
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

quassi

New mouth — Harbour mouth — Light house

*						ha					*	
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

t625alpha1

New mouth — Harbour mouth — Light house

*						ha					*	
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

e526z

New mouth — Harbour mouth — Light house

*						ha					*	
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

Bottle t525a

New mouth — Harbour mouth — Light house

*						ha					*	
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

g) **e6161.**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

h) **e 518 a**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

I) **T507A**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

j) **t519g**

New mouth *   Harbour mouth ha   Light house *

p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

k) **e86fox1.**

New mouth *   Harbour mouth ha   Light house *

p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

l) **e golf 2**

New mouth *   Harbour mouth ha   Light house *

p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

m) **e**

New mouth * | Harbour mouth (ha) | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

n) **t430bravo3.**

New mouth * | Harbour mouth (ha) | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

o) **po610alpha**

New mouth * | Harbour mouth (ha) | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

p) **e425b**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

q) **e 619e**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

r) **t425b**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

s) **e18-5**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

t) **e 425b**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

u) **t610br**

New mouth * | Harbour mouth | Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

v) **po423b**

New mouth * — Harbour mouth — Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

w) **e bravo 3.**

New mouth * — Harbour mouth — Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

x) **e617alpha**

New mouth * — Harbour mouth — Light house *

						ha						
p1	o1	n1	m1	l1	k1	j1	i1	h1	g1	f1	e1	d1
p2	o2	n2	m2	l2	k2	j2	i2	h2	g2	f2	e2	d2
p3	o3	n3	m3	l3	k3	j3	i3	h3	g3	f3	e3	d3
p4	o4	n4	m4	l4	k4	j4	i4	h4	g4	f4	e4	d4
p5	o5	n5	m5	l5	k5	j5	i5	h5	g5	f5	e5	d5
p6	o6	n6	m6	l6	k6	j6	i6	h6	g6	f6	e6	d6

1-3
4-7
8-11

Figure 5.2 a) - x) Distribution of sightings for 23 individuals sighted within the Richards Bay study area.

Chapter 6

Conclusions and recommendations for future research

Humpback dolphins frequented the Richards Bay area throughout the study period. There was no apparent preference for turbid water, as documented in previous studies in KwaZulu-Natal (Durham 1994a). The majority of humpback dolphin sightings in the present study occurred in water depths of 12.4 -15.5 m which is congruent with other studies (Durham 1994a; Karczmarski 1996b; Jefferson *et al.* 1993). It is therefore suggested that water depth is probably the main factor dictating the distribution of *Sousa chinensis*.

Historical catch data indicated that a minimum of 72 dolphins have been caught since deployment of the Richards Bay shark nets in 1980. An average of 3.79 (S.D. ± 3.08) dolphins per year were caught throughout the 19 year period. Surprisingly, the number of nets (total length of netting) does not appear to influence the number of dolphins caught in the Richards Bay installation. It is proposed that one of the main reasons for humpback dolphin capture may be due to the initial unfamiliarity of "naive" dolphins entering the area with regard to the shark net installation.

Durham (1994a) proposed that the population of humpback dolphins along the coast of KwaZulu-Natal could be sub-divided into a number of sub-populations, one of which was the Richards Bay area. Generally, individual dolphins were seen for varying times in the Richards Bay area with certain individuals displaying "long term residency" during this study while others were seen infrequently and often only once. Long distance movement patterns (Durham 1994a; Karczmarski 1996b), as well as low levels of association, suggest that the population at Richards Bay may be characterised by seasonal movement for some individuals, arriving in the area during the winter months. This in turn may influence capture rates in the shark net installation. As increased rainfall in summer causes river lagoons to break their banks and release increased abundance of estuarine-associated fish into the marine environment. This increased abundance of preferred humpback dolphin prey (Barros and Cockcroft 1991) allows the humpback dolphins to spread out during the summer with restricted ranges in winter to areas around permanently open river mouths. These results disprove the hypothesis that the Richards Bay population may be considered "closed" with humpback dolphins exhibiting minimal migration. Similarly, Karczmarski and Cockcroft (1997) estimated the Algoa Bay population to be "open" at 200 - 400 individuals, with the estimators subject to downward bias due to heterogeneity (Hammond 1986). Therefore, the estimation of 213 (± 42.72 at 95 % confidence levels) animals in the present study, should be considered as a minimum estimate for the Richards Bay area.

This new population estimate is considerably larger than Durham's (1994a) estimate and suggests that the impact of the observed capture rate of humpback dolphins in the KZN shark nets may not become immediately apparent due to the apparent openness of this population. The effects of the continuous captures will only be noticed when the KZN population has reached very low levels. Since high levels of inbreeding apparently occur in the KZN humpback dolphin population Smith (1990), it was initially suggested that the population was isolated despite the open nature of the population. Additionally, no interaction between the two humpback dolphin populations on the south-eastern coast of South Africa (KZN and Eastern Cape provinces) is envisaged since movement over long distances approximating 1000 km seems unlikely (Karczmarski and Cockcroft 1997). It is therefore proposed that these two populations should be seen as separate management units, with the KZN population still being under severe human-induced pressure including incidental captures in shark nets, pollution, habitat destruction and over-fishing of the preferred prey species.

Humpback dolphins in the Richards Bay area indicated varying degrees of residency. Additionally, individuals identified from the present study were previously photographed in areas other than Richards Bay (Durham 1994; NSB collection). The identified individuals each exhibited limited preference for utilisation of certain regions within the study area, rejecting the hypotheses that individual dolphins display similar residency patterns and no differences in home range and movement patterns within the study area. Site fidelity and home range data also imply that the Richards Bay area may form a "core area" for some humpback dolphins while others just pass through the area on either a regular or infrequent basis. It is therefore suggested that a similar population study be carried out in other areas either side of Richards Bay, e.g. St. Lucia and Zinkwazi. Such work would elucidate whether the intermediate sighting and capture frequencies found in Zinkwazi (Durham 1994a) represent a "core area" in itself, or whether the proposed Richards Bay "core area" stretches towards Zinkwazi and includes the entire Tugela Bank. This would be important to ensure effective management of the KwaZulu-Natal humpback dolphin stock.

Peaks in catch rates occurred from June to September, corresponding to an increase in the frequency of dolphin sightings in the harbour mouth area. Seasonal fluctuations in resource distribution and abundance could influence the distribution and movement of humpback dolphins on the KZN coast, in turn resulting in their capture.

In an attempt to reduce incidental captures of dolphins, it has been proposed to incorporate active acoustic devices (pingers) in the shark nets. Data for identifiable dolphin movements around the shark nets following pinger deployment was limited, resulting in insufficient evidence to conclude whether the acoustic warning devices used during the present study were efficient. Pingers had no discernible effect on individual humpback dolphin use of the area around the nets.

Individuals scoring high RI values were frequently observed within the netted area, but captured individuals scored low, or nil, RI values. This implies that unfamiliarity to a installation may be one of the factors influencing capture, suggesting that habituation through continuous exposure to acoustic warning would be minimal. The unfamiliar dolphins will have low levels of previous pinger exposure and the pingers would therefore conceivably contribute towards making these animals aware of the potential danger. Interestingly, most of the "resident" humpback dolphins frequented the netted area in Richards Bay without being captured. Data accumulated in this study were, unfortunately, insufficient to determine whether habituation may possibly be prevalent in the "resident" dolphin population.

However, limited data would suggest that the pingers do not act as an acoustic "aversive" device as claimed by the manufacturers. This finding is of considerable benefit to future possible incorporation of pingers in shark nets as these nets are inevitably laid in areas frequently visited by dolphins. Avoidance of these areas due to any aversive qualities in the pinger sound spectrum may, in turn, negatively affect the dolphins.

Due to the results obtained form this study, it is recommended that pingers be incorporated in the entire Richards Bay shark net installation as the next step into evaluating their efficacy in reducing incidental dolphin captures. If such a pinger experiment proves successful through reducing the by-catch of humpback dolphins in the Richards Bay area, the deployment of pingers throughout the KZN shark net installations may conceivably impact upon dolphins and their capture in two different ways:

a) Reduction in the efficacy of the device due to habituation following previous exposure to the sound in the individual's normal home range or preferred area, resulting in the ignoring of the sound and capture in an unfamiliar netted area;

b) Maintenance of a reduced dolphin by-catch in the shark nets due to previous exposure to pingers by most dolphins. If animals entered an unfamiliar area with active pingers in the shark nets, they could associate the sound of the acoustic warning device with nets and then proceed more carefully, resulting in lowered captures.

In conclusion, this study indicates that the continuous monitoring of the KZN humpback dolphin population is imperative to detect any change in their current status. It appears that humpback dolphins may still be severely impacted through ongoing catches in shark nets, making it essential to find a way to reduce this by-catch. It is therefore recommended that efforts into assessing alternative methods of bather protection be continued, while pingers are included in all shark nets in the interim.

Summary

During the last 19 years a minimum of 72 humpback dolphins *Sousa chinensis* were retrieved from the Richards Bay shark nets. Recently developed acoustic warning devices led to the introduction of these devices (pingers) into the shark nets at Richards Bay in an attempt to reduce the number of humpback dolphins captured in the nets. With the KwaZulu-Natal population set at approximately 200 animals this step led to the conception of the Richards Bay Humpback Dolphin Project. The present study was designed to obtain data that would reflect the state of the humpback dolphin population frequenting the Richards Bay area. The study was conducted during April to October of 1998 at Richards Bay (28° 48' S, 032° 06' E), on the eastern coast of KwaZulu-Natal.

Humpback dolphins frequented the Richards Bay area throughout the study period with the average group size being 8.72 (± 5.13). Data suggests that the Richards Bay area may be a suitable nursery area, since "females" with calves in close attendance, were frequently sighted in the study area. Humpback dolphins were seen most frequently in the southern and harbour mouth region of the study area and these areas most likely represent preferred areas.

Collection of biotic and abiotic data throughout the study area, such as water visibility, water temperature and ocean depth were used to correlate any noticeable environmental differences in area utilisation of humpback dolphin groups found in the study area. Only water depth seemed to limit the distribution of this species. No preference for turbid waters were evident during the study. Little or no preference for certain water temperature regimes were evident.

Analysis of capture data of humpback dolphins in the Richards Bay shark nets revealed an average capture rate of 3.79 (S.D. ± 3.08) dolphins per year during the 19-year period of installation. The number of dolphins captured in relation to the total length of nets in the particular installation do not seem to be correlated. Peaks in captures existed during the winter months (June to August). Humpback dolphin follows within the harbour and harbour mouth occurred primarily from June to August, the period which coincided with the dolphin captures of 1998 in the Richards Bay installation. Differences in seasonal utilisation and movement of humpback dolphins may lead to an increase in the

number of dolphins caught during the winter months within the Richards Bay shark net installation.

The number of newly identified individuals did not decrease with time, suggesting that the population sampled at Richards Bay may appear to be an open population. Using all identified individuals sighted during this study, a population of 213 (± 42.72 at the 95% confidence level) individuals was calculated. The continual discovery of new individuals in conjunction with some individuals exhibiting long distance movements along the coast, indicate that a large part of the sampled population does not constitute dolphins actually "resident" within the study area. As the majority of the identified individuals (63 %) were only photographed once within the study area, unfamiliarity may be one of the main reasons contributing to the high humpback dolphin capture rate in the Richards Bay installation. Unfortunately social structure estimates of humpback dolphins were severely hampered by irregular movements of dolphin groups.

Active acoustic deterrent devices (pingers) were introduced during June 1998 into the Richards Bay shark net installation in an effort to reduce the rate of capture of humpback dolphins in the shark nets. Humpback dolphins frequented the netted areas with and without pingers in place and even though three dolphins were caught in the shark nets, no final conclusion could be made about to the efficacy of the pingers, as all three captures took place during non-active pinger (dummies) periods. Continued investigation into the efficacy of the pingers is therefore needed. The observed site fidelity and home ranges indicated that the Richards Bay area may be for some individuals a "core area" or "preferred area" while others individuals just pass through. Humpback dolphins studied in the Richards Bay area displayed differences in site fidelity and had distinct levels of residency to the study area, affected by various unknown factors.

In conclusion, the continuous monitoring of the KZN humpback dolphin population is imperative, to ascertain any change in the current status, as population depletion in conjunction with mass habitat destruction, usually go un-noticed and unchallenged.

Opsomming

Gedurende die afgelope 19 jaar was 'n minimum van 72 boggelrugdolfyne *Sousa chinesis* uit die Richardsbaai haainette verwyder. Onlangse ontwikkeling van akoestiese alarm-apparate het gelei tot die gebruik van hierdie apparate ("pingers") in die haainette van Richardsbaai om die getal boggelrugdolfyne wat in die nette gevang word te verlaag. Aangesien die KwaZulu-Natal bevolking op om en by 200 diere geskat, het dit gelei tot die totstandkoming van die Richardsbaai Boggelrugdolfyn Projek. Die huidige studie was ontwerp om die status van die boggelrugdolfyn bevolking, wat die Richardsbaai area besoek, te weerspieël. Die studie was gedurende April tot Oktober 1998 in Richardsbaai (28° 48' S, 032° 06' E), op die ooskus van KwaZulu-Natal, uitgevoer.

Boggelrugdolfyne het die Richardsbaai area reg deur die studie periode besoek, met 'n gemiddelde groep grootte van 8.72 (± 5.13). Die Richardsbaai area is miskien 'n geskikte pleeg-area, aangesien "koeie" met kalfies in nabye sorg, gedurig in die studiearea gesien is. Boggelrugdolfyne was meestal in die suidelike en hawemond gedeelte van die studiearea gesien, en hierdie areas verteenwoordig heel waarskynlik voorkeur areas.

Versameling van biotiese en abiotiese data regdeur die studiearea, soos water sigbaarheid, water temperatuur en oseaan diepte was gebruik om enige sigbare omgewings verskille in gebieds-benutting deur boggelrugdolfyn groepe, in die studiearea, te korroleer. Slegs water diepte beperk die verpreiding van hierdie spesie. Geen voorkeur vir troebel water was waarneembaar gedurende die studie nie. Min of geen voorkeur vir sekere temperatuur stelsels was klaarblyklik nie.

Ontleding van vangste data van boggelrugdolfyne in die Richardsbaai haainette, het 'n gemiddelde vangkoers van 3.79 (± 3.08) dolfyne per jaar, oor die laaste 19 jaar van installasie heen, opgelewer. Die getal dolfyne wat gevang is in verhouding met die totale lengte van die net in die spesifieke installasie blyk nie gekorreleerd te wees nie. Pieke in vangste bestaan gedurende die winter maande (Junie tot Augustus). Agtervolgings van boggelrugdolfyne het meestal gedurende Junie tot Augustus in die hawe en die hawemond plaasgevind, die periode wat hoofsaaklik ooreenstem met die vang van dolfyne gedurende 1998 in die Richardsbaai installasie. Verskille in die seisoenale gebruik en beweging van boggelrugdolfyne het gelei tot die toename in die getal dolfyne wat gedurende die winter maande in die Richardsbaai haainet installasie gevang is.

Die getal nuut geïdentifiseerde individue het nie met tyd verminder, wat aandui dat die Richardsbaai bevolking 'n oop bevolking is, gegrond op die bekende individue wat gedurende die studie gesien is, is 'n beraming van die bevolking ongeveer 213 (± 42.72 by die 95 % sekerheidsvlak) individue. Die konstante identifikasie van nuwe individue, in samehang met individue wat lang afstand beweging langs die kus toon, dui aan dat slegs 'n gedeelte van die bevolking "inwoners" van die studiearea is. Aangesien die meerderheid van die geïdentifiseerde individue (63%) slegs een keer in die studiearea gefotografeer is, blyk dit asof onbekendheid met die Richardsbaai installasie een van die hoof redes is wat bydra tot die hoë boggelrugdolfyn vangkoers. Beramings van sosiale struktuur van boggelrugdolfyne was ongelukkig erg benadeel deur die ongereëlde beweging van dolfyn groepe.

Aktiewe akoesties afweer-apparate ("pingers") was in die Richardsbaai haainet installasie gedurende Junie 1998 aangebring, in 'n poging om die vangkoers van boggelrugdolfyne in die haainette te verminder. Boggelrugdolfyne het die net area beide met en sonder "pingers" gereeld besoek, alhoewel drie dolfyne in die nettegevang is. Geen finale gevolgtrekking kon gemaak word in verband met die effektiwiteit van die "pingers", aangesien al drie dolfyn vangste gedurende onaktiewe "pinger" (fop-instrument) periodes gevang is. Deurlopende ondersoek in die effektiwiteit van die "pingers" is noodsaaklik. Die waargenome gebiedsgebondenheid en tuisgebied het aangedui dat die Richardsbaai area miskien vir sekere individue 'n "kern-area" of "voorkeur-area" is, terwyl ander individue slegs deur die area beweeg. Boggelrugdolfyne, bestudeer in die Richardsbaai area, het verskille in gebiedsgebondenheid en onderskeie vlakke van residensie getoon, wat deur verskeie onbekende faktore beinvloed is.

Ter afsluiting; die voortdurende monitering van die KwaZulu-Natal boggelrugdolfyn bevolking is noodsaaklik, om enige verandering in hul huidige status vas te stel, aangesien bevolking vermindering in samewerking met grootskaalse habitat-vernietiging, meestal ongesiens en ongehinderd voortgaan.

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