Southern right whales wintering in the Auckland Islands

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Summary

Historically, southern right whales were widely distributed in New Zealand waters. This population, was driven to commercial extinction following extensive exploitation during the early 19th century (Dawbin 1986). It was further depleted by illegal Soviet hunting in 1950-1970 (Tormosov et al. 1998). While right whale sightings around mainland New Zealand remain rare, up to 165 whales can be found at the Auckland Is in a single day during winter. Despite what appears to be adequate habitat along the eastern coastline, the whales' distribution is largely limited to Port Ross, Laurie Harbour and waters around Enderby I. The relatively small area where so many whales congregate means that at peak season the density of whales at the Auckland Is is very high (approximately 8 whales/km^2). The residency period extends from at least early May to at least the end of September, with peak numbers in July and August. Cow/calf pairs utilise most areas within Port Ross and Laurie Harbour, and show a preference for shallow waters. The photographic catalogue contains 410 animals (including 76 cows) and capture-recapture analysis suggests that the size of the population is likely to be between 740 and 1140 animals. The low level of gene flow between this population and the southwestern Australia population and other wintering grounds underlines the uniqueness of the Auckland Is population. The Auckland Is are currently the primary calving and breeding ground for southern right whales in New Zealand waters. Long-term monitoring programmes should be directed at the continued annual collection of photographs for individual identification, investigating the location of the feeding grounds and developing a sighting and photo-identification network for southern right whales around mainland New Zealand.

1. Introduction

Most species of great whales have been the target of an extensive whaling industry in Europe, America and Asia and subsequently in Southern Hemisphere countries. As a result of world-wide exploitation, many great whale species numbers were reduced to levels less than 5 or 10% of their original abundance (Walsh 1967, Schevill 1974, Best 1993). One of these severely depleted species is the southern right whale *(Eubalaena australis)*.

Right whales are large, stocky baleen whales, predominantly black with occasional white blazes on their underside and chin. Some whales also show variation in pigmentation, including light brown, mottled grey, and white-phase observed in a small proportion of calves (Payne et al. 1983, Best 1990, Payne 1990). They reach an estimated maximum weight of 80 to 100 tons, and average about 14 m in length, with females slightly larger than males, and newborn calves range between 4.5 m and 6 m in length (Jefferson et al. 1993). Right whales are easily identifiable at sea as they lack a dorsal fin or ridge and their widely separated nostrils create a V-shaped blow when they exhale. Their

head is also a distinguishable feature from other whales; as it is covered with areas of roughened skin to which cyamid amphipods or whale lice (*Cyamus* spp.) attach (Matthews 1938). These `callosity patterns' are unique to each individual and change little over time, making them a useful feature for photographic capture-recapture studies (Payne 1983, Kraus et al. 1986).

Southern right whales are distributed throughout the Southern Hemisphere, generally inhabiting waters at 20-60° latitude (Townsend 1935). As with many baleen whale species, they are thought to migrate between high latitudes during summer feeding and warmer, coastal waters in lower latitudes to calve and breed during winter. Based on the distribution of 19th century catches, the International Whaling Commission recognises 13 winter calving grounds of southern right whales, two of which are found in New Zealand waters: New Zealand main land/Kermadecs and New Zealand subantarctic (Anonymous 1998). Prior to the study summarised in this report, only four of the 13 putative stocks representing three breeding grounds are showing signs of recovery: Eastern and Western Africa, Australia and Argentina (Payne et a1.1990, Best 1990, Bannister 1990).

The southern right whale species is listed as lower risk/conservation dependent (IUCN 1996). This designation implies that although they are showing signs of recovery, the continued recovery is dependent on ongoing conservation programmes, the cessation of which would result in the species qualifying for one of the threatened categories within a period of five years.

Historically, southern right whales were widely distributed in New Zealand waters and numbered more than 10 000 individuals (Dawbin 1986). Following extensive exploitation during the early 19th century, right whales in New Zealand waters were considered commercially extinct by the 1840s. Although protected from hunting by international agreement since 1935 right whales were hunted illegally by the Soviet whaling fleet from 1950 to 1970 (Yablokov 1994, Tormosov et al. 1998). As a consequence of the intensive and prolonged hunting, recovery of southern right whales has been slow, and sightings in the historical calving grounds around New Zealand mainland/Kermadec Is remain infrequent.

In the subantarctic islands, the pattern of recovery has differed. Sightings of southern right whales in this area in winter months have increased during the last 50 years. Whales have been sighted in small numbers at Campbell Island since the 1940s and at the Auckland Islands for the last two decades (Gaskin 1964, Gaskin 1968; Cawthorn 1978, 1986, 1988, 1993, 1995; Donoghue 1995; Stewart & Todd, 1998).

The Auckland Is are located 460 km south of mainland New Zealand (50° 33' S, 166° 15'E. The main island (Auckland) is approximately 40 km long and 25 km at its widest (Fig. 1). The western coast of the main island is exposed and offers no sheltered areas, while the eastern coastline has an almost continuous series of large embayments. At the north-east end, Port Ross leads southwest into Laurie Harbour and has Enderby Island to the north. This marine area of approximately 20 km2 is about 9 km long, with a maximum width of 3 km narrowing to 500 m in Laurie Harbour.

The Royal New Zealand Air Force (RNZAF) reported 70 whales in the Port Ross area in July 1992 (M. Donoghue, pers. comm.), and 42 adults and one calf in August 1993 (Donoghue 1995). In 1995, the University of Auckland and the New Zealand Department of Conservation jointly conducted the first winter scientific expedition to these islands. This and subsequent expeditions confirmed that southern right whales aggregated in large numbers at the Auckland Islands during winter months (Patenaude et al. 1998, Patenaude & Baker in press).

This report reviews the current demographic and genetic status of New Zealand southern right whales at the Auckland Is in relation to five management-related questions by the Department of Conservation. These are:

1. What is the sensitivity of the Auckland Is for southern right whales?

2. What are the critical areas and periods at the Auckland Is when southern right whale cows and calves are present in highest numbers, and most vulnerable to potential anthropogenic disturbance?

3. What is the estimated population size of southern right whales at the Auckland Is?

4. What is the international significance of the Auckland Is southern right whale population?

5. What is the most cost-effective way of monitoring long-term trends in the status of the Auckland Is southern right whale population?

The analysis and results reported in this document are largely based on research conducted in and around Port Ross during four consecutive Austral winters from 1995 to 1998. A research team visited the islands from mid July to early August in 1995-97, and from the third week of June to third week of August 1998. The details of field work methodology, analysis and results can be found in Patenaude et al. (1998), Baker et al. (1999) and Patenaude & Baker (in press).

2. Site sensitivity

2.1 OBJECTIVE

Determine the sensitivity of the Auckland Is by describing the age, gender and activities of southern right whales at the Auckland Islands.

2.2 METHODS

In order to determine the extent of the distribution of whales around the Auckland Is, a small boat survey was conducted in 1995 in the waters off the

north and eastern shores of Auckland main island (Patenaude et al. 1998). In 1996, a helicopter chartered by the TVNZ Natural History crew was used to survey the length of the Auckland Is, including Carnley Harbour, for right whales.

In order to determine the minimum number of southern right whales visiting the Auckland Is each winter, combined non-systematic small boat and shore-based surveys of right whales were conducted within Port Ross and surrounding areas (Fig. 2; Patenaude et al. 1998, Patenaude & Baker in press). The boat surveys were conducted along the centre-line of the harbour, and visibility (during most surveys) allowed scanning to the extent of both coastlines. Simultaneously, other observers conducted shore-based counts from several elevated vantage points on Enderby and Auckland Is. During these surveys, a sighting was considered to include only one individual unless more than one individual could be counted at the surface within one and a half whale body lengths. Thus these censuses represent a minimum estimate of the number of whales observed on each occasion.

Site utility was determined by recording right whale group size, composition and behaviour prior to approaching each group. The behavioural categories chosen were those commonly recorded in other southern right whale breeding grounds (see Appendix 1 for description of behaviour categories). Boat handling around the whales was conducted so as to minimise the possibility of disturbance. Attempts were made to avoid biases in group observations and sampling by regularly changing the location of data collection, zigzagging within the harbour and attempting to approach each group sighted.

For all observations, an animal was judged to be a calf when the portion visible at the surface was less than half of the length of an accompanying adult (Hamilton & Mayo 1990). The accompanying adult was assumed to be the cow.

Right whales are not apparently sexually dimorphic, and sexing of animals is virtually impossible unless an animal rolls on its back and exposes its genital slits or is closely associated with a calf and assumed to be a cow. In order to determine the sex ratio of animals at the Auckland Islands, small skin samples were collected using a compound bow with a biopsy dart similar to that described by Brown et al. (1991). Total DNA was subsequently extracted from these samples (Sambrook 1989) and the sex of each biopsied individual was determined by amplification and restriction digest of a Y-chromosome marker (Palsboll et al. 1992).

2.3 RESULTS

Local distribution

At the Auckland Is, southern right whales were almost exclusively concentrated in the waters surrounding Port Ross and around Enderby I. Each year, a few whales were also sighted in Matheson Bay. During the boat survey along the northern and eastern coastline of the main island in 1995, two whales were sighted along the north-east coast in Haskell Bay, and one whale was

sighted deep in North Harbour along the north coast (Fig. 1). Observers on the helicopter that surveyed the length of the Auckland Islands in 1996 confirmed that the main aggregation of right whales was limited to Port Ross/ Laurie Harbour. No whales were sighted in Carnley Harbour or along the western coastline of Auckland I. (B. Doak, pers. comm.).

Whales were present in Port Ross and Laurie Harbour in high concentrations throughout the study period during all four winter seasons. Minimum counts from one-day shore- and boat-based surveys varied from 96 whales (including 9 calves) in 1995 to 165 whales (including 15 calves) in 1998 (Fig. 3).

Group size and behaviour

The group size, composition and activity of right whales were recorded on 358 occasions. From 1995 to 1998, almost one third of the groups approached were composed of three or more individuals (n=103) and social/sexual activity was predominant within these groups (83%; Appendix 1). Other behaviours observed in singletons or groups included resting at the surface, and almost 20% of singletons approached the research boat. In 71% of these latter cases, these animals were sexed by molecular method as females. There were few observations of directional travel by singletons (10%) or groups (<15 %) and fewer observations of feeding (<1%). On one occasion, presumed feeding behaviour was observed when a single whale repeatedly surfaced with its mouth open. The TVNZ Natural History film crew also documented a whale travelling with mouth open, apparently pumping water with its tongue below the surface (`The Lost Whales' Natural History Unit documentary, 1997).

Mating activity was taking place in most of the social groups as evidenced by abundant whitewater, erect penises and females exposing their bellies to the surface. In addition, the TVNZ film crew documented intromission between a male and a female in 1996 (`The Lost Whales' Natural History Unit documentary, 1997). About 66% of animals present in groups engaged in social/sexual activity were males (n=86). Overall, the molecular identification of sex of biopsy sampled animals indicated that, although engaged in differing activities, males and females are found in equal numbers at the Auckland Is.

Cow/calf pairs

Of the 358 groups encountered for which behaviour was recorded, 23% were cow/calf pairs or cow/calf pairs and escorting adults (Appendix 1). Most (64%) of the cow/calf pairs encountered were sighted resting at the surface, and 36% were observed travelling. Several episodes of riding above the mother's back were also observed. Many calves sighted were very small with wrinkled skin, and appeared to have difficulty swimming. Some of these calves also had foetal folds suggesting they were newborn.

On two occasions we were able to document approximate date of parturition for photo-identified females. The first female (Id *365) was sighted on 8 July 1998 resting for 36 minutes with two other adults. Three days later it was photographed with a very small calf and accompanied by an adult. A second female (Id * 230) was sighted on 21 July 1998 travelling slowly and later resting alone at the surface. Subsequently this whale was sighted on 12 August

1998 with a very small calf and again four days later with its newborn and accompanied by an adult.

2.4 DISCUSSION

The observations collected during the 1995-98 field seasons indicate that the Auckland Islands are an important habitat for southern right whales. The distribution of whales is largely limited to Port Ross, Laurie Harbour and waters around Enderby I. Despite what appears to be adequate habitat along the eastern coastline and the protected Carnley harbour at the southern tip of the main island, cow/calf pairs and other whales are seldom found at these other locations. This distribution is consistent with the location of whales previously reported from a RNZAF flight in 1993 (Donoghue 1995).

High numbers of whales were present in all four winter seasons. The relatively small area where so many whales congregate (20 km^2) means that at peak season the density of whales at the Auckland Is is very high (approximately 8 whales/km^2) for the overall Port Ross/Laurie Harbour area. In comparison, at the Head of the Bight in South Australia, reported to be the largest and densest aggregation and nursery area of the Australian population, the maximum count on any single day in 1993 was of 45 adults (including 20 cows) (Burnell & Bryden 1997) in an a area spanning approximately 20 km of shoreline. Whales are generally found within 1 to 1.5 km of shore in this area. Including all adults and calves, the local density would equal about 3 whales/ km^2 at the Head of the Bight. In Argentina, the recent shift in distribution from Golfo San Jose to Golfo Nuevo recorded the highest mean density of whales in Golfo Nuevo. With 12 whales along a 5-km segment of coastline, this would equal approximately 2.5 whales/ km^2 (Rowntree et al. 1998).

Within Port Ross and surrounding areas male and female right whales are present in high numbers, and are most often found in social groups engaged in apparent sexual activity. Cow/calf pairs constitute about a quarter of the whales present (although seasonal variation occurs, see below) and there is clear evidence that whales are giving birth within Port Ross/ Laurie Harbour. Although some breeding grounds can be roughly separated into 'mating' and `calving areas', e.g. South Africa (Best 1970, 1981), this is not the case in the Auckland Is. Although the high latitude of the Auckland Is is more consistent with known summer feeding grounds worldwide, they are clearly both a calving and breeding ground for southern right whales.

Southern right whales are also reported in small numbers along the northwest coast of Campbell Island (52° 32'; 169° 05'); Gaskin 1964, Donoghue 1995, Stewart &Todd 1998). There is photographic evidence of both within- and between-year movements of whales between Campbell I. and Auckland Is (Patenaude et al in press). This suggests that the two aggregations are part of one intermingling population, with the Auckland Is being the predominant site of the two in both size of the aggregation and extent of calving. There is insufficient information to conclude if there is age or sex class subdivision between the two regions, but in recent years no cow/calf pairs have been sighted at Campbell Island (Stewart & Todd 1998).

The low levels of sightings around mainland New Zealand and the low numbers reported at Campbell Is indicate that the Auckland Islands are the primary wintering habitat for southern right whales in New Zealand waters. Because all land masses are regularly visited within New Zealand waters, it is highly unlikely that another undiscovered site of equal importance exists. Presently, the Auckland Is are the only known significant calving ground of southern right whales in New Zealand, and in the South-west Pacific.

3. Critical area and periodicity

3.1 OBJECTIVE

Identify the a) critical areas and b) periodicity when cows and calves are highest in abundance and therefore most vulnerable to potential anthropogenic factors.

3.2 METHODS

In order to determine the areas where cow/calf pairs are in greatest abundance within Port Ross, directed surveys were conducted from aboard a motor/sailing vessel in 1996 and 1997. During each survey (two per year), the vessel moved around Enderby and criss-crossed Port Ross and Laurie Harbour in an attempt to approach every cow/calf pair in the area. Cow/calf pairs were located and photographed, and their location was noted on a map with 1 km grids. Groups without calves were ignored.

The seasonal variation in abundance of southern right whales in the Port Ross area was assessed by conducting weekly combined shore- and boat-based surveys from 22 June to 20 August 1998. The surveys generally followed the same methodology described in Patenaude et al. (1998). Two observers aboard a small boat conducted a survey along a set track at approximately 8 to 10 knots and marked all groups observed on to a grid map (Fig. 2B). At the same time, a single observer scanned all shores of Enderby island by sectors for periods of 10 min. and recorded the approximate locations of all whales observed at the surface. Possible duplicate counts determined by mapped location were excluded. The surveys yielded minimum abundance counts and also allowed to plot the location of cow/calf pairs during the extended field season.

In addition, S. Childerhouse opportunistically recorded right whale sightings during spring and autumn visits at the Auckland Is for sea lion research in 1996-2000.

3.3 RESULTS

The location of cow/calf pairs plotted during weekly surveys in 1998 indicate that they utilise most areas within Port Ross and Laurie Harbour throughout the season, although there may be seasonal variation in the use of some areas. Interestingly, during directed surveys conducted in 1996 and 1997, about 90% of the 78 sightings of cow/calf pairs were in waters less than 20 m deep and all but three sightings were within 500 m of shore (Fig. 4). From the end of June until mid July 1998, most cows were found along the east and western shores of Laurie Harbour (see Appendix 2 for plotted locations during weekly surveys). Starting in mid July, cow/calf pairs were increasingly found in the open waters of Port Ross and around the north and eastern coasts of Enderby I.

Weekly surveys conducted in 1998 indicated that the abundances of cow/calf pairs and other whales vary throughout the winter season (Fig. 5). The first, conducted on 24 and 26 June were incomplete surveys of two separate areas, the northern coast of Enderby Island (24 June) and Port Ross and Laurie Harbour (26 June). Combining these gives an approximate count of 82 whales, including two cows and two calves, for the end of June. By early July until the end of August, at least 100 whales were consistently counted in the Port Ross area, with peak numbers (n= 165, including 15 cow/calf pairs) occurring on 15 July. The abundance of cows and calves showed a steady increase in absolute count throughout the field season, and peaked during the third week in August (n=38 cow/calf pairs; Fig. 5). By this time more than 57% of animals counted were cows or calves.

Although no specific surveys of the area were conducted outside of the dedicated field season, there are reports of whales in low numbers in early May and several whales present by the end of September. On 9 May 2000, the DOC sea lion observation team sighted a total of seven whales (three whales off the eastern coast of Enderby 1. and four whales in Port Ross). No whales were sighted in Laurie Harbour. Between 23 September and 3 October 1997 this team sighted a minimum of four cow/calf pairs and an estimated total of 40 whales in Port Ross and Laurie Harbour (S. Childerhouse, pers. comm.).

3.4 DISCUSSION

Based on four years of observations and surveys, it appears that the entire Port Ross area and surrounding waters are utilised by cow/calf pairs throughout the winter season. There may be some change in local use from Laurie Harbour to outer Enderby as the season progresses, but overall there is no evidence that a specific location is preferred by cow/calf pairs. Rather, the entire area comprising the waters of Port Ross, Laurie Harbour and Enderby I. are habitats highly utilised by cows and calves. There is some indication that cow/calf pairs prefer shallower waters near shore, but this preference may not be exclusive to this group. An analysis of distribution of whales according to depth showed that 78.5% of whales in Port Ross were sighted in waters of 20 m or less (Barrett 2000). Although the factors attracting right whales to areas of coastline are not well understood, it is probable that the preference

for shallower waters may be a contributing factor to the whales' distribution with the Auckland Island. The waters of Port Ross offer a unique habitat as they are relatively calm for this southern latitude, giving shelter from prevailing winds, and are also quite shallow, with depth of less than 40 m. Many of the embayments on the east coast have greater charted depths, and the large and protected Carnley Harbour located further south has most of its waters at depths of 40-80 m.

The residency of right whales at the Auckland Is extends from at least early May to at least the end of September, with peak numbers in July and August. There is historical evidence that right whales once visited the Auckland Is as early as 10 April (Dingwall et al. 1999). It is clear that by the third week in June there is a significant aggregation of right whales, including at least some cow/calf pairs, at the Auckland Is. The peak abundance of non-cow/calf animals occurs in mid July while cow/calf pairs show a steady increase in numbers as the season progresses. By the 18 August there were still at least 133 whales present, of which 38 were calves, and the number of cow/calf pairs did not show signs of decline. Although the seasonal variation in abundance reported here is based on a single field season, it is identical to that reported for its closest geographic neighbour population in South Australia. Burnell & Bryden (1997) report that whales have been sighted at the Head of the Bight in early May, and numbers peak in July and August before declining in early October. This suggests that the residency reported here may well be representative of the true seasonal abundance of right whales at the Auckland Is.

During the 1998 special meeting on the worldwide status of right whales, the IWC scientific committee made recommendations regarding habitat related issues, specifically addressing the monitoring of human activities at the Auckland Is. The report stated: *"Recognising that the entire known breeding population of New Zealand subantarctic southern right whale concentrates in a very small area, and that adverse effects of human-related activities could potentially have a serious impact on this recovering population, the Committee recommends that any existing or proposed human-related activities in the New Zealand subantarctic (e.g. whalewatching, oil or gas exploration, vessel traffic and fishing operations) be carefully evaluated and monitored for any potential negative effects."*

4. Population size estimate

4.1 OBJECTIVE

Calculate the population size using capture-recapture analysis based on individual identification photographs.

4.2 METHODS

Photographs of callosity patterns, lip ridges and unusual skin pigmentation were collected for individual identification of southern right whales (Payne et al. 1983; Kraus et al. 1986). Photo-identification was conducted from small vessels (4-6m) and at times from the deck or mast of a larger chartered vessel (20-30 m) in the winters of 1995-1998. Details of photographic collection are found in Patenaude et al. (1998). Effort was directed at photographing the left profile of each whale, from bonnet to post-blowhole callosities.

Photographs were compared within years to determine the total number of unique whales each year (captures) and then compared between years to determine the number of animals re-identified (re-captures). The photographic catalogue was reviewed by four researchers experienced with right whale photo-i.d. (B.Todd, S. Kraus, M. Mark and P. Hamilton). To reduce the potential of heterogeneity due to poor quality photographs, only photographs of good or fair quality were used for the capture-recapture analysis.

Abundance estimates were generated from several mark-recapture models using the programs CAPTURE (Otis et al. 1978) for closed models and JOLLY (Pollock et al. 1990). Closed models assume that there is demographic closure in the population, implying that there is no recruitment or loss during the study period (Begon 1979). Open models allow for the effects of migration, mortality and recruitment in the population. All mark-recapture models are subject to several assumptions. These include: 1) being caught has no effect on an individual's subsequent chance of capture (variation of capture among sampling occasions), 2) all individuals have an equal chance of being captured (heterogeneity of individual capture), and 3) animals have an equal survival rate (constant survival rate). The models in CAPTURE and JOLLY programs were designed to relax a combination of these assumptions and recommend the most appropriate model for the data based on a goodness of fit test. Details of models and assumptions can be found in Darroch (1959), Otis et al. (1978), Seber (1982), Begon (1979), Jolly (1965), and Pollock et al. (1990). In addition, a Chapman's modified Petersen estimator was used, with the 1995-1997 data pooled as the first capture and the 1998 data used as the recapture (Seber 1982).

4.3 RESULTS

A total of 383 individually identified whales, including 72 known cows, have been photographically catalogued between 1995 and 1998. More than half (52%) of the animals were identified in 1998. The larger proportion of whales identified in 1998 corresponds to the increased length of the field season and photographic effort in that year. An additional 27 new whales were photographed by B.Todd in 1999, increasing the total number of individual identifications to 410, including 76 known cows.

Of the 383 animals identified, 49 were resighted twice, 12 were resighted three times and only one was resighted in all four years. Estimates generated from different models varied widely (456 to 1600) with 95% confidence in-

tervals from 226 to 2054. The open models estimates were generally lower than those generated by the closed models, with three of the four estimate ranges falling below the minimum number of photo-identified whales. Although there was no detection of evidence of breakdown of closure based on the frequency of captures (z-value=0.047, p=0.519), demographic closure is unlikely to be true, as southern right whale females are known to give birth on average every 3 to 3.5 years and are usually absent from the calving grounds in years prior to giving birth (Payne et al. 1990, Best 1990, Bannister 1990). As a result of this lack of true closure, estimates are likely to be biased upward.

4.4 DISCUSSION

Estimating whale population parameters from photo-identification has been used on several cetacean species including right whales (Payne et al. 1983, Best & Underhill 1990, see IWC (1990) special issue on cetacean photo-identification). When estimating population size based on mark-recapture models it is important that the assumptions of the models are satisfied. Two of the most important considerations are closure and heterogeneity of capture. The former is rarely met in nature because of birth, deaths, emigration and immigration. Violations of the assumption of closure creates an upward bias in population estimate while heterogeneity in capture data causes a negative bias (Pollock et al. 1990).

Because estimation techniques for closed populations are generally based on fewer parameters than those of open models, the techniques are generally preferred, as they provide more precise estimates of population size if the closure assumption is valid (White et al. 1982). Many open and closed models have attempted to compensate for heterogeneity of capture with various degrees of success (Otis et al. 1978, Pollock et al. 1990). In general, closed models are generally more robust to heterogeneity of capture.

Southern right whale females are known to give birth on average every 3 to 3.5 years and are rarely present on wintering grounds in years prior to giving birth (Payne et al. 1990, Best 1990, Bannister 1990). This, coupled with different residency length between age and sex classes (Burnell & Bryden 1997) strongly suggests that heterogeneity of capture exists in right whale populations. To alleviate this problem, other right whale population size estimates have been based on longitudinal studies (more than 20 years in some cases) of females with calves. In the Auckland Is population, the photographic data collection is constrained by the short time series and the limited number of identified parturient females. In this case, the entire photo-identification dataset was used regardless of sex and reproductive status. The compromise is to prefer a model more robust to heterogeneity of capture (i.e. closed model) while attempting to minimise the effect of lack of closure. Pooling the 1995,1996 and 1997 dataset as the first capture and using 1998 as the recapture approximates closure by minimising the effect of cycling females and new recruits into the population. Using this method, the estimated size of the Auckland Is southern right whale population is likely to be between about 740 and 1140. This estimate is not directly comparable to those published for other wintering grounds. Furthermore, the estimate is constrained by the

short time series, and it is unclear to what extent the heterogeneity of capture and the lack of true closure affects this population estimate. Subsequent estimates may be larger or smaller depending on these underlying factors.

5. International significance

5.1 OBJECTIVE

Determine the international significance of the Auckland Is southern right whale population by assessing the extent of differences in the distribution of mtDNA lineages from other wintering populations in the southern hemisphere.

5.2 METHODS

A selection of samples of skin tissue were collected by biopsy darting from southern right whales on wintering grounds of south-west Australia (n = 20) and the Auckland Islands (n = 20). Details of the methods for biopsy sampling method are found in Patenaude et al. (1998). Total DNA was subsequently extracted from these samples by standard molecular methods (Sambrook 1989; as modified by Baker et al. 1994). A previously identified variable region of the mysticete mtDNA control region (Baker et al. 1993; Medrano-Gonzalez et al. 1995) was amplified and sequenced from each individual (Baker et al. 1999).

A phylogenetic tree of the mtDNA sequence types (or haplotypes) was constructed using parsimony analysis with the computer program PAUP (Swofford 1993). The geographic differentiation of haplotypes between the Auckland Is and Western Australia population was quantified using the analysis of molecular variance procedure (AMOVA; Excoffier et al. 1992). Details of the statistical analyses are found in Baker et al. (1999). AMOVA calculates the standard variance components and an array of correlation measures of the haplotypes for population structure, either by considering entire sequence information or only categorical differences between haplotypes. These are referred to as *phi*- and F_{ST} statistics (Wright 1951,Weir 1984, Hudson et al. 1992).The significance of the observed *phi*- and F_{ST} values is tested using a matrix permutation procedure (Baker et al. 1999).

In addition, the rate of female migration between the two populations was estimated using the approximation $Nm_f = (1 - FST)) / 2 FST)$ (Wright 1951; Takahata & Palumbi 1985).

5.3 RESULTS

A total of seven unique mtDNA haplotypes were found in the two populations. Two of the seven haplotypes were found on both the Auckland Is and

Western Australian wintering grounds. Five types were only found on one or the other wintering grounds (Fig. 6). Phylogenetic reconstruction suggested that these haplotypes form two clades, each of which was dominant on one wintering ground. The AMOVA showed significantly non-random distributions of mtDNA lineages between the two wintering grounds (phi $_{ST}$ = 0.157, p = 0.017; Baker et al. 1999).

The observed differentiation of mtDNA between the Auckland Is and Western Australia populations suggested that average long-term gene flow has been limited to only a few females per generation ($Nm_f < 5$) despite the absence of obvious geographical barriers (Baker et al. 1999).

5.4 DISCUSSION

Baker et al. (1999) found significant differences in frequencies of mtDNA haplotypes between the Auckland Is and Western Australia samples. The demographic and genetic structure of these populations, as reflected in migratory movement of individuals and the distribution of mtDNA lineages, indicates strong maternal fidelity to the Auckland Is. This local site fidelity could increase the risk of inbreeding and constrain the recolonisation of the New Zealand southern right whale's historical range even if there is an increase in abundance. It was also noted that the genetic diversity at the Auckland Is is very low, suggesting a loss of diversity had resulted from past exploitation (Baker et al. 1999).

The pattern of genetic differentiation between the Auckland Is and Western Australia southern right whale populations has also been reported for the Argentinian and South African populations (Portway et al in press). Furthermore, preliminary analysis of the combined datasets from all four breeding grounds shows that all four southern right whale populations are genetically distinct from each other and that there is very low level of gene flow between all populations (Patenaude et al. 1999).

The southern right whale species is still at less than 10% of its pre-exploitation size (IWC 1998). The International Whaling Commission recognises the uniqueness of the New Zealand subantarctic stock for which the Auckland Is is the main calving and breeding habitat (IWC 1998). The distribution and diversity of mtDNA is a function of the historical demography and behaviour of females within each population (Avise 1996). The level of philogeographic structure observed between all four breeding grounds implies a considerable degree of demographic autonomy among the populations. This implies that the management of each population needs to be addressed individually.

6. Long-term monitoring of southern right whales at the Auckland Is

This report shows the Auckland Is to be the primary calving and breeding ground for southern right whales in New Zealand waters. Despite four years of research, there are still many questions left unanswered. In order to better understand and monitor trends in population recovery, a long-term monitoring programme needs to be implemented with the aims to detect trends in abundance over time and to gain information on distribution, movement and other life history parameters. The monitoring programme of southern right whales should be directed at the following goals:

1) to improve the estimate of the number of reproductive females and reproductive rates,

2) to detect trends in abundance over time,

3) to monitor existing and potential threats,

4) to gain information on the location of summer feeding grounds, and

5) to gain additional information on other wintering habitats, including mainland New Zealand and Campbell Is.

Improve the estimate of the number of reproductive females and reproductive rates

Yearly photo-identification collection of parturient females will allow the determination of calving cycles and improve capture-recapture estimates of this component of the population for comparison with studies of other southern right whale stocks. This is essential information to adequately estimate population size of reproductive females and to determine trends in recruitment rates. Because of the added problem of the breeding cycle of southern right whale females, it has been suggested that at least five breeding cycles (i.e. 15 years) would be required to obtain significant results for breeding females (Bannister, in press).

It is recommended that collection of photographs directed at parturient females be continued on an annual basis for at least three consecutive breeding cycles.

Detect trends in abundance over time

In other southern right whale calving grounds, monitoring programmes have been in place for several years, and in some cases several decades (Bannister 1990, Payne et al. 1990, Best 1990). Existing programmes in Argentina, South Africa and south-west Australia combine aerial surveys and individual photo-

identification data collection as a means to monitor trends in population size. The field conditions of these programmes differ in several ways from those of the Auckland Is. In all the cases mentioned above, the right whale populations are found within a few kilometres of the mainland, but dispersed over a great length of coastline. The remoteness of the Auckland Is and the variable weather conditions limit the extent of `cost-effective' options. However, the whales are highly localised within a small area, enabling large quantities of data to be collected without the need for extensive surveys.

The rate at which trends in population size are detected depends on the rate of change in the population, the precision of the estimate, and the interval between estimates (Gerrodette 1987). Given annual population estimates, it would take 9 years to detect a 5% rate of increase in the population for a coefficient of variation (c.v.) of 0.11 with a 95% statistical confidence (based on power analysis, Gerrodette 1987). As the number of years between surveys increases, or the true rate is less, so does the number years it will take to detect change (Gerrodette 1987).

The accuracy of the estimate is proportional to the sampling intensity. The higher the number of captures, the higher the number of potential resightings and in consequence the smaller the c.v. (Begon 1979, Gerrodette 1987). Given the estimated population size of the Auckland Is population, it would take about 120 individually photographed animals per survey to obtain an accuracy of 0.10 using Jolly-Seber's open model (Begon 1979). The number of animals captured will need to increase each year as the population size increases. Fewer captures would decrease the precision of the estimate and in consequence it would take a longer time to detect a trend. For example, it would take 14 years to detect a 5% rate of increase if the c.v. is 0.22.

To detect a trend in abundance, it is recommended that the monitoring plan include provisions to collect photo-identification of at least 120 different individuals annually for a period of 10 years.

To date, the photo-identification catalogue held at the University of Auckland has been limited to the left lateral view of the callosity patterns. Over the course of the four years of field work, right sides, and topside photographs have also been collected opportunistically but in significantly fewer numbers. Photographic programmes in other wintering grounds of the southern hemisphere have been directed at topside photography only.

It is recommended that photo-identification collection should include both lateral and topside views of each animal to enable matching to the existing Auckland Is catalogue and to other southern hemisphere catalogues, particularly Australia.

Photographs of right whale callosity patterns can be collected from an aircraft (fixed-wing or helicopter), from an elevated platform aboard a vessel and/or from shore. In past years, photo-identification has been collected from the deck or mast of a vessel and/or from shore. Photography from a vessel, unless from an elevated platform, will limit the collection of topside photographs but provide comparable lateral profiles. Unlike photography from an aircraft (see below), a vessel charter to the Auckland Is has the advantage of

allowing a larger research team to conduct additional field work. For instance, biopsy sampling can be conducted in parallel to photo-identification collection, and a second team can conduct topside photography from cliff-tops. In past years of research, vessel charters were supported in part by other teams conducting work at the Auckland Is (e.g. sea lion research) to reduce costs.

Alternatively, photographs can be collected from an aircraft. In this case, the aircraft must allow clear view for photography (i.e. camera port or high wing) and be capable of flying at relatively slow speeds (80-100 knots), at altitudes of 100 m or less to allow circling the whales for data collection. In view of the distance from the mainland and the lack of landing strip at the Auckland Is, round-trip flights aboard fixed-wing aircraft need to be conducted when prolonged weather forecast is good. It has yet to be determined if a fixed-wing aircraft can manoeuvre safely at low altitudes within Port Ross and Laurie Harbour. Photographing right whales aboard a helicopter may cause some disturbance to the whales. Bowhead whales were found to be more sensitive to helicopters than to fixed-wing aircraft, especially at low altitudes (<150 m; Patenaude et al in review). Whether by fixed-wing aircraft or helicopter, photographs collected will be of topside only and may limit the possibility of matching to the catalogue in its current form.

It must also be recognised that in order to avoid biases created by the seasonal change in frequency of different age-sex classes, aerial surveys need to be planned for a number of days across the season.

It is recommended that photo-identification collection be conducted from aboard a vessel during peak abundance of whales (July-August).

Monitor existing and potential threats

In view of the sensitivity of the Auckland Is for southern right whales, potential and existing anthropogenic threats to the population need to be monitored. Entanglement in fishing gear and ship strikes have been shown to significantly affect the recovery of right whales in the North Atlantic (Kraus 1990). Monitoring the effects of these activities at the Auckland Is is possible by evaluating the rates of entanglement and vessel strike scaring over time through the collection and examination of photographs (Hamilton et al. 1998).

Photographs of the animals may also be useful to monitor the health of the population. A small percentage of southern right whales at the Auckland Is have been sighted with what appear to be tumours on their backs. Although the origin and nature of these apparent growths is undetermined, opportunistic sightings over four years suggests that the proportion of animals exhibiting this pathology is on the increase (N. Patenaude, pers. obs.).

It is recommended that photographs of scars and unusual growths be collected to monitor the potential effects of human activities. It is recommended that the nature, extent and trend of the observed 'growths' be documented by photographs and biopsy sampling.

Investigate the location of feeding grounds

There is no information available on the habitat or range of the Auckland Is southern right whales outside the breeding season. Although 19th century whaling data suggest a seasonal migration towards higher latitudes during summer months (Townsend 1935), the feeding grounds of the Auckland Is population are unknown. Determining the destination of right whales when they leave the islands is essential to better monitor this population throughout its entire range. The location of the groundscan be determined by matching photographs collected during aerial or boat surveys to the existing catalogue, or by satellite tracking..

Until the location of the feeding grounds for the Auckland Is population is narrowed down, surveys are not cost-effective, as they would require several surveys to cover the extensive area where right whales could be found feeding. Satellite tracking technology that uses Argos satellite positioning systems provides the opportunity to determine movement patterns over an extended period of time. The North Atlantic right whale tagging programme has been in place for 10 years. Improvements in design, durability and longevity of the attachment mean that whales can now be tracked successfully for up to two months at a time without adverse effects to the whales (Goodyear 1993, Mate et al. 1997). Deployment of satellite-tags late in the winter season (e.g. September) would be a means of determining the location of the breeding grounds, or at least the direction taken when whales leave them.

It is recommended that a satellite monitoring programme be initiated to identify the feeding grounds for the Auckland Is population. Results from the year 2000 programme in the North Atlantic can be reviewed to assist in cost and efficiency of tags.

Gain additional information on other wintering habitats

Comparisons of photographs of the Auckland Is catalogue and of photographs collected at Campbell I. by Project Tohora provides evidence of both within- and between- year movements of southern right whales between the islands (Patenaude et al in press). However, there is insufficient information to conclude if there is age or sex class subdivision between the two regions. It is recommended that additional photographs of left lateral profiles of whales wintering at Campbell I. be collected and compared with the Auckland Is catalogue to further document the extent of interchange.

It is recommended that photographs for individual identification and skin biopsy samples of southern right whales at Campbell I. be collected. An initial sample of 20 skin biopsies should be collected to determine the sex of whales by molecular method, and to compare the genetic status mtDNA of these animals to the Auckland Is and other right whale populations.

It is unclear whether the occasional right whales sighted around mainland New Zealand are the remnant of a historically separate stock, occasional visitors from the Auckland Is, or part of another separate stock (e.g. Australia). Efforts should be directed at providing local DOC staff with the means to collect at least photographs of the left profiles of callosity patterns, and where

possible skin samples of right whales sighted around mainland New Zealand. A centralised database should also be set up to collect all sighting information.

The size of population and the small area used at the Auckland Is suggests that whales are likely to expand their range as the population grows. Sightings around mainland New Zealand could increase as a result of this expansion. Monitoring the rate of sightings over time could provide an indicator of the range of this expansion.

It is recommended that a network for sighting and photo-identification of southern right whales be developed around the New Zealand mainland.

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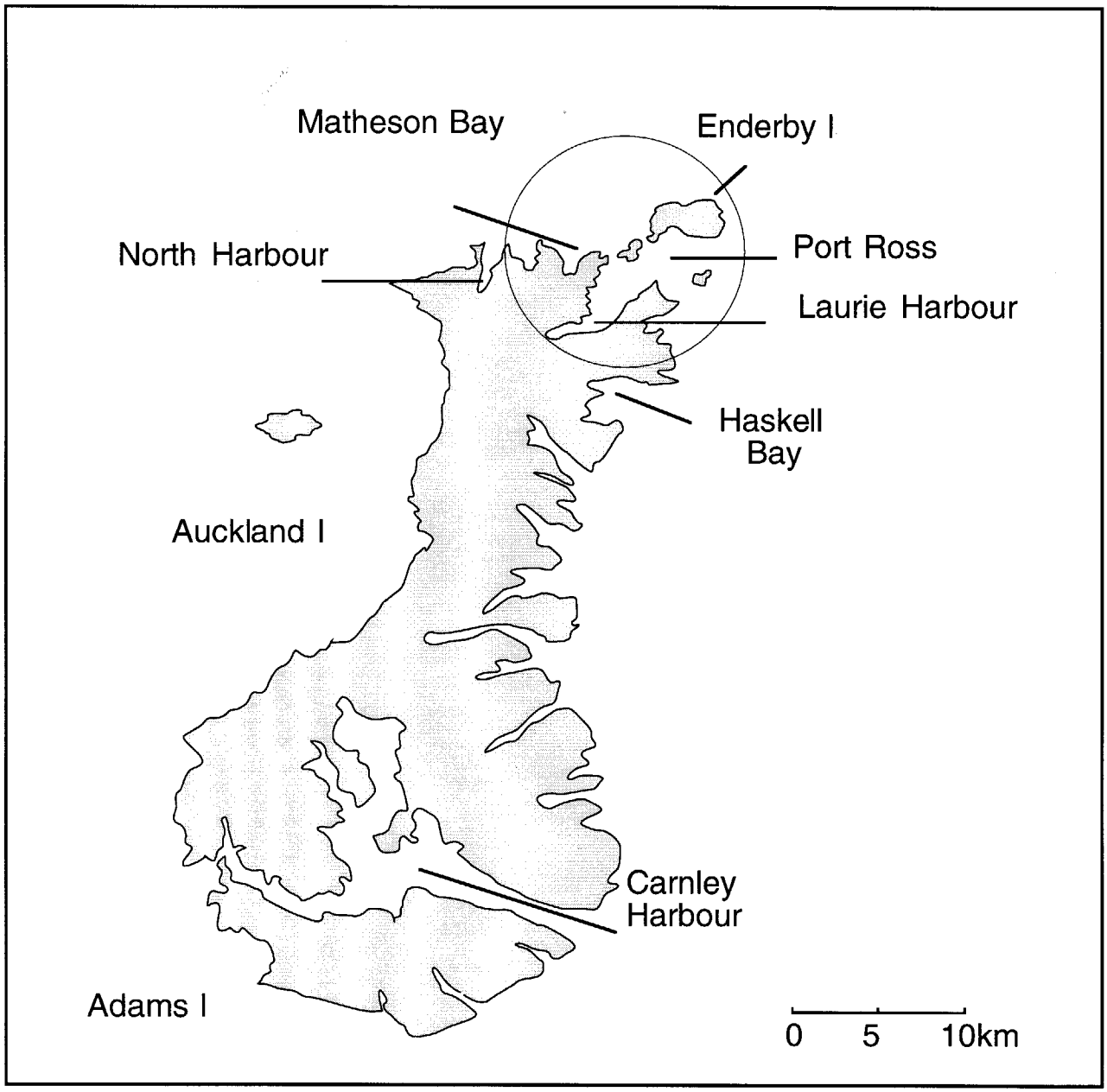

Figure 1. Map of the Auckland Islands with area of concentration of southern right whales encircled

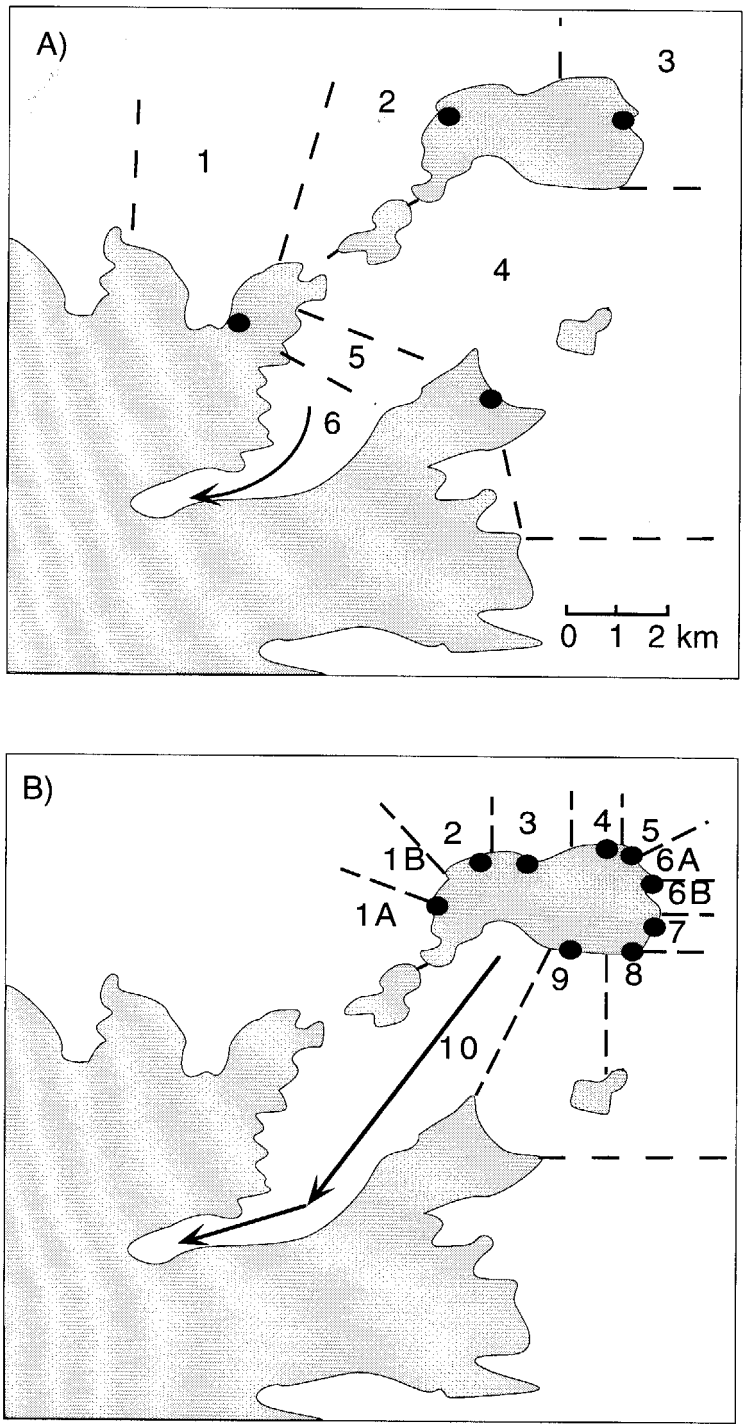

Figure 2. A) Map of study area divided into sectors showing shore-based observation points (circles) and path of boat survey (arrow) during simultaneous surveys of sectors in A) 1995-1997 and B) 1998.

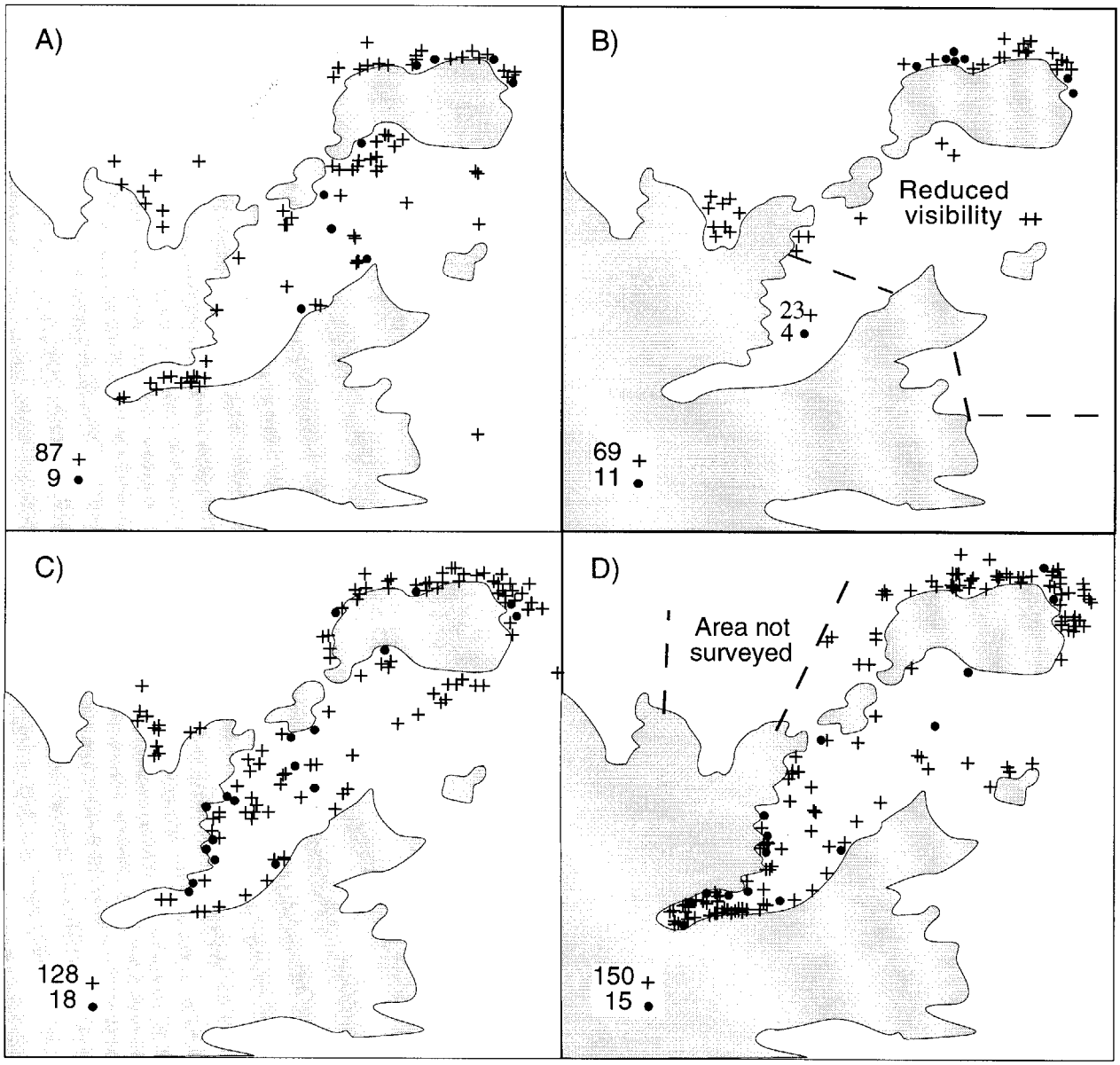

Figure 3. Location of whale sightings during minimum counts on A) 6 August 1995, B) 6 August 1996, C) 28 July 1997 and D) 15 July 1998. Location of whales was unrecorded during the 1996 boat survey. Filled circles represent cow/calf pairs, crosses are other whales.

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