Orca (*Orcinus orca*) in New Zealand waters

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This thesis is dedicated to all the orca in New Zealand waters,
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"When I think back to all the crap I learnt in High School, it's a wonder I can think at all"
Paul Simon (1973)

"The only way to survive an encounter with a killer whale is reincarnation"
Hoyt (1984)

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ABSTRACT

Orca (*Orcinus orca*), also known as killer whales, are more widely recognised than other marine mammals. Although they have been reported from all oceans of the world, including the seas around New Zealand, information above anecdotal notes exists for only a few places. Orca are an apex marine predator that exhibits cultural differences in diet, vocalisations, and behaviour, between and within populations. This study was established to determine baseline information on New Zealand orca and to provide recommendations for future management and conservation. The conservation status of orca worldwide is poorly known, although two populations of the Pacific North West Coast of North America have recently been classified as 'Threatened' and 'Vulnerable'.

Photo identification was used to determine the population size, distribution around New Zealand waters, as well as range use and association among individuals. The total New Zealand orca population is small (range 65-167 animals, with 115 calculated alive in 1997). Resighting rates were high, with 75 % (n = 88) of the animals seen on more than two occasions. The mean number of sightings for the 117 photo-identified animals was 5.4, the mode was one sighting, and the median 9 – 10 sightings. One orca was photographed over a 20 year period. Population structure, frequency of association with others, and other social behaviours were used to determine population demographics. The New Zealand orca population appears to be made up of at least three sub-populations based on geographic distribution (North-Island-only, South-Island-only and North+South-Island sub-populations). Preliminary mtDNA analysis supports the hypothesis that some New Zealand orca do not mix. The mean Association Indices within the North-Island-only and South-Island-only sub-populations are significantly greater than within the North+South-Island sub-population. Those animals sharing food had higher Association Indices than those who did not share food. Sex ratios appear similar within each sub-population and calves were present in each, suggesting all sub-populations are breeding.

Feeding behaviour was observed to assess habitat use and differences between foraging strategies and prey preferences. Twenty four different species of prey have been recorded in the New Zealand orca diet. Of these, ten have not been recorded elsewhere. The prey consists of four types; rays (the most common food type), sharks, fin-fish and cetaceans (pinnipeds have not been identified as a prey source). Foraging strategies were different for each prey type, with benthic foraging for rays in shallow waters the most diverse strategy used in New Zealand. Food sharing was observed for all prey types. One of the three proposed New Zealand sub-populations appears to be generalist or opportunistic foragers, feeding on all four prey types, another sub-population slightly less so, feeding on three prey types, and the third sub-population appears to be a more specialist forager, only recorded taking one prey type (cetaceans).

Potential threats to orca, in addition to small population size, such as bioaccumulation of toxic chemicals, oil spills, boat strikes and shootings are considered and recommendations for conservation and future management are offered.

Whether the three sub-divisions within the New Zealand orca population are reproductively isolated and hence require separate management, and whether there is further sub-division within the proposed North+South-Island sub-population, requires further study including genetic analysis. Some level of ongoing monitoring is recommended to ensure that the population of New Zealand orca does not decline.

In addition, records of stranding locations and details of strandings are appended. Twenty-four live strandings occurred, involving 63 killer whales, of which 17 animals were successfully refloated and two of these resighted. One was seen after three years (nine resightings) and the other after four months (10 resightings). Refloating stranded orca is recommended.

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CHAPTER ONE

Orca (*Orcinus orca*), a focal species in biodiversity conservation

Global Biodiversity

Functioning ecosystems provide a range of resources and services important to people (Costanza *et al.* 1997, Daily 1997). Basic life sustaining functions such as oxygen production, carbon, water and climate regulation, soil formation, and pollination are necessary for life, including human life. Such processes rely on the presence of biodiversity as the living components of ecosystems. These resources are also used directly by humans for food, fuel, fibres, medicine etc., and indirectly for aesthetic reasons (Hunter 1996).

Biodiversity is defined by the Convention on Biological Diversity as "*The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part, this includes diversity within species, between species and of ecosystems*" (Anon. 1998).

Despite the total reliance of humans on biodiversity, the rapidly expanding human population is placing ever increasing demands on nature. The outcome is ongoing alteration, including loss and fragmentation of ecosystems resulting in continuing loss of biodiversity (Jenkins 1992).

The current worldwide biodiversity crisis can best be described as a reduction in this diversity of life at a rate that greatly exceeds any previous rate, including the reduction seen in the fossil record (Anon. 1998, Wilson 1992). The majority of these losses are directly attributable to the actions of humans.

The United Nation's meeting in Rio de Janeiro (1992) attempted to address this and other environmental problems. The Biodiversity Convention resulting from that conference requires signatories, such as New Zealand, to produce a Biodiversity Strategy. New Zealand recently published a strategy (Anon. 1998) which clearly articulates a long-term and ongoing loss of biodiversity and suggests options for response.

New Zealand's Marine Biodiversity

The desired outcomes for marine environments listed in the New Zealand's Biodiversity Strategy include that, by 2020, there should be no human-induced extinctions of marine species in New Zealand's marine environment; that rare or threatened marine species are adequately protected; and that marine biodiversity is appreciated (Anon. 1998). This same strategy states that as much as 80% of New Zealand's indigenous biodiversity is found in the sea, and acknowledges that marine areas are actually more diverse and distinctive than were previously realised. Thirty-three of the 34 recognised animal phyla occur in the sea, 15 of them exclusively (Murphy and Duffus 1996).

Although oceans, coastal waters and estuaries constitute, by volume, more than 99% of the Earth's habitat for plants and animals (Murphy and Duffus 1996), the fact that more is known about land-based ecosystems and their biodiversity, compared to the marine environment, is well established. Ballantine (1991) stated "…. *ignorance is the normal state of affairs in any marine consideration*". One of the main reasons for this opinion is our very limited knowledge about the marine environment. Irish and Norse (1996) found that only 5% of papers published in the journal

Conservation Biology focused on marine biodiversity, compared to 9% freshwater and 67% terrestrial biodiversity. However, Craig *et al.* (1995) found the New Zealand public rated marine reserves as a high priority for management, and rank greater availability to information on their natural heritage as the most important conservation management issue.

This lack of information applies to marine mammals as much as other marine species. Although the Marine Mammal Protection Act was ratified in 1978, only six of the 35 species seen in New Zealand waters have been studied to any extent. It was only in the 1980's and 1990's that robust information on the status and distribution of a few New Zealand marine mammals became known (e.g., Childerhouse *et al.* 1995, Cipriano 1992, Dawson 1991, Dawson and Slooten 1988a, Dawson and Slooten 1988b, Dawson *et al.* 1995, Pichler *et al.* 1998, Russell, 1999, Schneider 1999, Slooten 1991, Slooten and Dawson 1988, Slooten and Dawson 1994, Slooten and Dawson 1995, Slooten *et al.* 1992, Slooten *et al.* 1993, Walker and Ling 1981, Williams *et al.* 1993). The species investigated included; Hooker's sea-lion (*Phocarctos hookeri*), Hector's (*Cephalorhynchus hectori*), bottlenose (*Tursiops truncatus*) and dusky dolphins (*Lagenorhynchus obscurus*), southern right (*Eubalaena australis*) and sperm whales (*Physeter macrocephalus*), with the Hector's dolphin being by far the most studied marine mammal in New Zealand waters. The main issues and threats to these marine mammal populations are outlined in Slooten and Dawson (1995), as well as those for the New Zealand fur seal (*Arctocephalus forsteri*) (which is also found in Australia).

With the exception of the work on Hector's dolphins by Slooten and Dawson (e.g., see above), the research on most of New Zealand's marine mammals tends to be piecemeal and of short duration. The Hector's dolphin study clearly identified conservation concerns that led to New Zealand's first marine mammal sanctuary (Dawson and Slooten 1993). In contrast, in other countries, more long term studies of marine mammals are available (e.g., Hammond *et al.* 1990).

New Zealand is an archipelago of hundreds of islands (Towns *et al.* 1990). Its early separation from Gondwanaland over 82 million years ago (Cooper and Millener 1993) resulted in New Zealand having no native ground-dwelling mammals. Our only native mammals are two species of small bats (Taylor and Smith 1997) and 35 species of marine mammals (Baker 1983). Perhaps because only one dolphin and one sea lion species are endemic, whereas the other marine mammals disperse more widely through the oceans, and because there has been a long history of exploiting marine mammals as a resource, New Zealand has largely ignored its responsibilities in the conservation of marine mammals. Such a response contrasts markedly with the long history of absolute protection for migratory birds (New Zealand Wildlife Act, 1953).

In New Zealand there are only two areas under protection specifically for marine mammals, one for Hector's dolphins off Banks Peninsula (Dawson and Slooten 1993) and one for Hooker's sea-lions off the Auckland Islands (MAF and DoC 1991). Both of these areas were created to protect the species from fishing pressures due to by-catch. Neither addresses the problem of habitat protection, nor the need to manage issues such as prey abundance and water quality. Although it is outside the Department of Conservation's (DoC) jurisdiction, it may require a joint effort through DoC, Ministry of Fisheries, Ministry for the Environment, and Regional Councils to address these issues.

Slooten and Dawson (1995) suggested that fishing may have an indirect impact on marine mammals by reducing prey abundance and a direct impact through net entanglement. Perrin *et al.* (1994) listed thirty-one of the world's forty species of dolphins and porpoises to have suffered mortality in gillnets. The remaining nine are regarded as either too large (e.g., orca, *Orcinus orca*), very rare (e.g., spectacled porpoise, *Australophocaena dioptrica*) or having sub-Antarctic distributions (e.g., hourglass dolphin, *Lagenorhynchus cruciger*) to be at threat from net entanglement. However, in New Zealand at least two orca were caught and died in a net, whilst another was caught and either shot or stabbed before being cut loose and subsequently died (Visser 2000). Another form of fishing is direct targeting of cetacean species for ‘scientific whaling’ which could affect stocks that migrate past New Zealand (Bhagat 1999, Easthorpe 1996, Perry 2000, Slooten and Dawson 1995, Visser 1999a).

The threats to marine mammals are mainly issues such as environmental changes (e.g., rising sea temperatures), food source depletion from commercial fishing, sediment out-flow, pollution and by-catch (Slooten and Dawson 1995, Taylor and Smith 1997). Slooten and Dawson (1995) point out that pinnipeds may also be under threat from shooting, and this is also the case for orca (Visser 2000).

Habitat degradation and ship collisions are also listed as threats to New Zealand marine mammals (Slooten and Dawson 1995). Reference is made to boat strikes as being uncommon, but they did state that they photographed an orca with large propeller scars, who has since been identified as NZ25 (Visser 1999b, S. Dawson and L. Slooten, pers. comm.). However, boat strikes may pose more of a threat to orca than was first realised (Visser 1999b, Visser and Fertl 2000).

Biodiversity Conservation Management

For effective biodiversity management purposes, the unit of management actions is typically a population of a species (Towns and Williams 1993). This is clearly the approach adopted by land-based conservation management in New Zealand, as typified by the tuatara (*Sphenodon punctatus*), kokako (*Callaeas cinerea*) and takahe (*Notornis mantelli*) programs (e.g., Cree and Butler 1993, Crouchley 1994, Rasch 1992). There are many different definitions of a species, and the way it is defined can have significant ramifications for conservation management. Therefore, it is generally agreed that the extinction of any local population can be viewed as being as important as the extinction of a whole species, especially if the local population is genetically, morphologically or culturally distinct.

Caughley (1994) presented two threads for Conservation Biology, the first is the small-population paradigm where the population is under threat from extinction due to the intrinsic nature of the size of the population. The second is the declining-population paradigm where processes external to the population are driving them to extinction.

Small populations, variously described as less than 500 (Soulé 1987) or less than 10,000 (Mace and Lande 1991), are at risk from random processes that may lead to chance loss of reproductive individuals, genetic variability, etc. Indeed, Mace and Lande (1991) suggested three categories of extinction threat related to these values, but built in declining population options as well. For example, their highest category, "critical", included any two of the following: total population < 250; or more sub-populations of < 125; or 20% annual decline; or population subject to catastrophic crashes.

The small-population paradigm has a strong theoretical base (Caughley 1994) although its operational imperatives are questioned (Craig 1994, Hendrick *et al.* 1996). To maintain biodiversity, minimum population numbers in 100's to 1000's are assumed preferable and species with populations below this are considered in need of urgent action. An example; the total Hector's dolphin population is believed to number 3 000 – 4 000 (Dawson and Slooten 1988a) and in urgent need of conservation management, due to its small population. This is especially true for the population off the North Island (Russell 1999). In addition, all Hector's dolphin populations are under threat from the ongoing impact of by-catch.

The declining population paradigm relates more to issues of negative change to habitat, including features such as pollution, by-catch, and reduction of prey abundance (for marine mammals see above). This paradigm relies on practical experience and has little scientific or theoretical support (Caughley 1994). Most management actions in response to this issue are *ad hoc* and relate to simple cause and effect assumptions (Caughley 1994). The overwhelming decline in New Zealand's native biodiversity (Anon. 1998) makes this the paradigm of most current management attempts.

Orca

Orca, also known as killer whales, have been reported from all oceans of the world (Heyning and Dahlheim 1988, Martinez and Klinghammer 1970). They are considered one of the easiest cetaceans (whales, dolphins & porpoises) to recognise as a species. Laymen's identification guides, such as Watson (1981) and Carwardine (1995), and review papers such as Heyning and Dahlheim (1988), all describe distinguishing features such as large dorsal fins (on males) and distinctive colouration. Although orca have a worldwide distribution, information above anecdotal notes exists for only a few places. These include the North Western Pacific (PNW) seaboard of North America (i.e., Canada, USA), Norway, Iceland, Argentina, and the Crozet Islands (Baird 1999, Ford and Ellis 1999, Ford *et al.* 1994, Guinet and Bouvier 1995, Matkin 1994, Sigurjonsson *et al.* 1988, Similä *et al.* 1996). The most detailed information is available for the PNW coast of British Columbia, Washington State and Alaska (Baird 1999, Bigg, 1982, Ford and Ellis 1999, Ford *et al.* 1994, Matkin 1994, Matkin *et al.* 1994, Olesiuk *et al.* 1990).

Orca are an apex marine predator that exhibit cultural differences in diet, vocalisations and behaviour between and within different populations (Baird 1994, Baird 2000, Ford and Ellis 1999, Ford *et al.* 1998). It is well established that different populations of orca worldwide are morphologically and culturally distinct (Berzin and Vladimirov 1983, Evans *et al.* 1982, Ford and Ellis 1999, Ford *et al.* 1998, Matkin *et al.* 1999, Mikhalev *et al.* 1981, Saulitis *et al.* 2000, Similä and Ugarte 1993). Although some of these populations have been defined, they have not been formally described (Heyning and Dahlheim 1988). However, to date, the species is considered monotypic by most authorities, with geographical variations between populations noted in size, colour pattern and diet (Klinowska 1991). These distinct populations are what could be termed 'evolutionarily significant units' which may consist of groups such as races or varieties (Vogler and Desalle 1994), or the distinctiveness may actually correspond to the subspecific level of classification given to terrestrial animals (Hunter 1996), which makes them the prime unit for conservation management.

Taylor and Smith (1997), in the New Zealand State of the Environment Report, refer to the global population of orca as "*Probably several hundred thousand*" quoting the IUCN 1991 Red Data List (this is actually an incorrect citing of the IUCN data). They also describe the New Zealand orca population status as "*Apparently common, but population trends unknown*", but provide no authority as the source of information, nor any further justification of this broad comment. Moreover, this comment fails to recognise the potentially highly localised distribution of the species and the need for all nations to manage the population(s) within their territorial waters. Most importantly, this approach ignores the importance of individual populations as the unit for conservation management and puts at risk, not only the genetic diversity within populations, but also the populations themselves, and ultimately the species.

The Relationship between People and Orca.

The core of the biodiversity problem is the actions of people. But the solution also lies with people. How people relate to nature influences their behaviour (Craig *et al.* 1995, Galbraith 1990, Orr 1992). Within the last decade, the human perception of apex predators has changed. For instance, wolves and mountain lions were often presented as the embodiment of evil but are now powerful and popular symbols of conservation groups (Hornocker 1992, Hunter 1996). Another predator whose image has changed is the orca. Their image has generally moved from aggressive killers who are a threat to humans, to 'lovable' symbols of majesty and power in the ocean world.

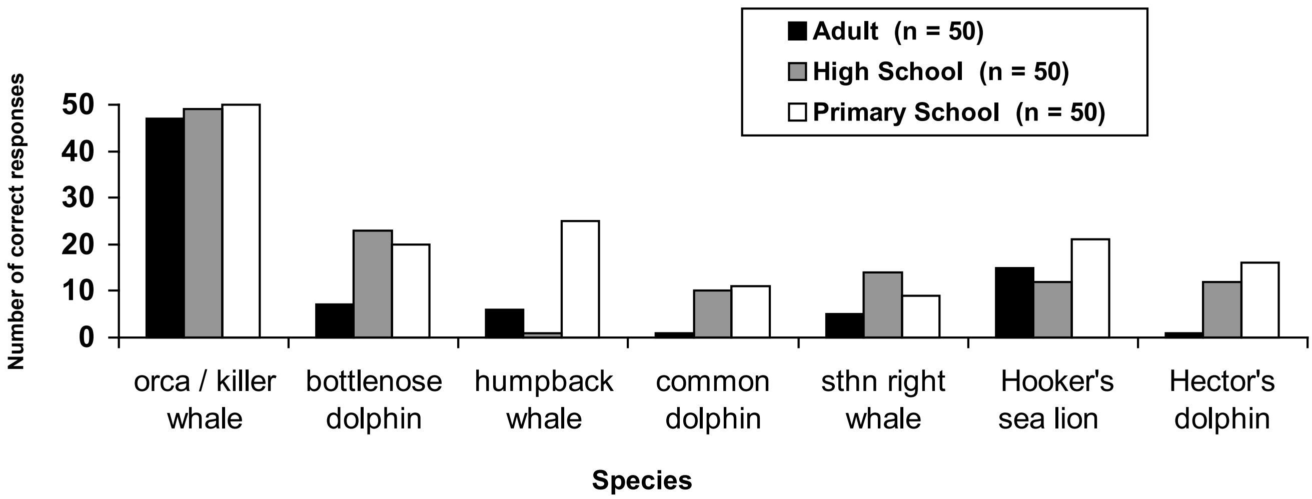
No matter where orca are found in the world, they are considered an apex marine predator, based on their diet, such as other marine mammals (Jefferson *et al.* 1991, Visser 1999c, Visser *et al.* 2000), sea birds (Guinet 1992) and elasmobranchs (Fertl *et al.* 1996, Visser 1999d). This perception has led to local common names that describe their predatory behaviour, such as: *killer whale* (English), *spekkhugger* (fat-chopper; Norwegian) and *späckhuggare* (fat-chopper; Swedish). Even the Latin name *Orcinus* means "of, or belonging to, the kingdom of the dead". An early United States diving manual (as quoted by Hoyt 1984) apparently stated *"The only way to survive an encounter with a killer whale is reincarnation*". Yet another book titled "Dangerous Marine Animals" has a section on 'killer whales' and states "*They are fast swimmers and will attack anything that swims. They have been known to come up under ice floes and to knock seals and people into the water. If killer whales are spotted, the diver should get out of the water immediately*." (Halstead 1959). In his book titled "Man is the Prey", Clark (1969) comments that the killer whale *"is the biggest confirmed man-eater on earth"*.

Some traditional societies such as the American Indian tribes of the Tlingit, Haida, Tsimshian, Kwakiutl and Coast Salish people revered the orca and regarded it as the spiritual lord of the sea. There was a widespread belief that an orca could drag a boatload of fishermen to the bottom of the sea and once there, the people would be transformed into orca. Orca appearing in front of villages were believed to be drowned persons returning to communicate with their families. These legends are kept alive today by books such as that by Lewis (1999). The stylised image of the orca, with its high dorsal fin and many-toothed mouth, was used on every day items and also appeared on totem poles (Ellis 1991). In New Zealand, Maori myths and legends pertaining to orca in particular are not known (Orbell 1995).

Orca are a well recognised species by the general public. In a survey of 150 people (of three different age groups) conducted in the Whangarei area (New Zealand), the vast majority (94 - 100

%) (Fig. 1.1) of people could identify an orca using drawings from guide books. A smaller number (2 – 32 %) identified a Hector's dolphin, New Zealand's only endemic dolphin, but a further 6.6 % identified a Hector's dolphin as a small or baby orca. None were able to name a Hooker's sea lion, New Zealand's only endemic pinniped. Six people (4 % across all ages) identified the Hooker's sea lion as a walrus. Although percentages differ in other areas of the country (for instance in the Christchurch area where Hector's dolphins receive a high media profile), the findings are indicative of general perceptions of orca worldwide (Hoyt 1992a).

Figure 1.1. Identification of Marine Mammals found in New Zealand



Over time, general worldwide perceptions of orca have changed. There is an increasing interest in 'whale watching' in the wild (Duffus and Dearden 1993, Hoyt 1992a) and orca are now considered one of the most spectacular of all cetaceans seen on whale watching trips (Duffus and Dearden 1993, Ford and Ellis 1999). They are the main attraction for facilities that hold them in captivity (Hoyt 1992b) and there is a high media profile with movies such as the 'Free Willy' series (Corliss 1993). Still, this change in perception has taken time and even today, many people fear being tipped out of boats or being attacked whilst in the water (Visser, unpubl. data).

The status of marine mammals worldwide varies considerably from species to species. The IUCN Red Data List for Dolphins, Porpoises and Whales of the World (Klinowska 1991) rated cetaceans according to seven different categories and listed orca as "*Insufficiently Known*". This inferred that the taxon were *suspected* (but are not definitely known, because of lack of information) to belong to one of the Endangered, Vulnerable or Rare categories. Since 1991 there have been two additional IUCN Red Data Lists published (IUCN 1996, 2000) (however the Klinowska (1991) report remains the only Red Data List specifically for cetaceans). The categories for listing all animals have been modified since the 1991 listing (IUCN 1996). In the IUCN (2000) version, orca are designated as 'Lower Risk, Conservation Dependent'. This now infers that where orca are the focus of a continuing taxon-specific or habitat-specific conservation programme, the cessation of that conservation programme would result in orca qualifying for one of the threatened categories, within a period of five years (IUCN 2000). However, conservation programmes, or acknowledgement that these programmes are required, are in place for only a limited number of orca populations, for instance the Canadian populations described in Baird (1999).

In addition, the IUCN (2000) has decided (under the 1996 guidelines) to list a 'global' assignment for all species first, and then work towards listings for subspecies and 'geographical populations' (R. Reeves, Cetacean Specialist Group IUCN, pers. comm.). For the global population estimates of orca, the IUCN (1991) report is very inconclusive and refers to sightings in different areas in terms such as *a few thousand, sporadic, frequent, clusters, occasional sightings, concentrations, regularly seen"*, but does list some numbers, where known. Adding up all the actual numbers listed, the world population is estimated at 70 thousand south of 60° S and 7367 north of 60° S. However, Klinowska (1991) goes on to say that it "*should be noted that killer whales occur in many areas other than those few in which studies have been conducted; thus totalling results of concurrent localised studies will still underestimate the aggregate population"*.

A few of these studied populations of orca have been monitored long-term, such as those along the PNW coast of North America (Baird 1994, Ford *et al.* 1994, Ford *et al.* 1998). This monitoring, and a recent review (Baird 1999), has led their national status in Canada (determined by the Committee on the Status of Endangered Wildlife in Canada) to be changed from 'Insufficiently Known' to two different classifications of 'Threatened' and 'Vulnerable' (Baird 1999). This split results from long-term monitoring of two separate populations in the area, and each one receiving a different status, based on their known distribution and numbers (Baird 2000).

On a worldwide scale, cetaceans have a high conservation profile and are often used as symbols of the conservation movement (Ellis 1991, Hunter 1996). There has been strong public pressure to protect cetaceans and through the initiative of World Wide Fund for Nature (WWF), the Southern Ocean Sanctuary (SOS) was established south of 60° (Donoghue 1995) to protect whales in the Southern Ocean should the moratorium be lifted on whaling. Although the New Zealand government was a signatory to the SOS, it has taken no further action in promoting, monitoring, protecting or policing the sanctuary. In fact, New Zealand allows Japanese whaling ships to refuel, reprovision and dock in New Zealand ports, yet these ships are actively hunting in the Antarctic Ocean south of New Zealand (Bhagat 1999, Easthorpe 1996). In New Zealand, since the early 1900's, orca were taken as by-catch for oil (Meers 1915) and for so-called 'scientific' purposes until at least 1979 (Mikhalev *et al.* 1981). They have been hunted on a commercial scale in Antarctica where more than 900 were taken in 1980 alone (Ellis 1991). This may have implications for the New Zealand orca population (Visser 1999a).

Thesis Aims

This study was established to determine baseline information on New Zealand orca, and to provide recommendations for future management and conservation. It utilises techniques such as photo identification to determine the population size, distribution around New Zealand waters and range use by individuals. Collation of information from public sightings is used to supplement field records (Chapter Two). Population structure, frequency of association with others and other social behaviours are used to determine population demographics (Chapter Three). Where possible, feeding behaviour was observed to assess habitat use and differences between foraging strategies and prey preferences (Chapter Four). All of these factors are considered important for establishing management units for conservation. A combination of this information, plus records of strandings (Visser in prep), observations of potential threats to orca such as boat strikes (Visser 1999b, Visser and Fertl 2000), frequency of abnormalities (Berghan and Visser 2000, Visser 1998) and shootings (Visser 2000) are combined to offer recommendations for conservation and future management (Chapter Five).

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CHAPTER TWO

Population Size & Distribution of orca (*Orcinus orca*) in New Zealand waters

ABSTRACT

New Zealand is facing a major biodiversity crisis and halting this decline has become a central issue. Management of individual species is a key factor, and in order for this to be effective, population information is required. This chapter presents population demographics for New Zealand orca. Data were collected from 'Historic', 'Public' and 'Research' sources (n = 1069 reports). The information was divided geographically into six 'Regions', and examined for monthly patterns. One-hundred and seventeen individual orca were photo-identified. The mean sighting period was 3.8 years and one orca was seen over a 20 year period. Sighting histories (distribution, range and longevity) are given for ten individuals, with one animal resighted 30 times. Fifty orca were resighted five or more times, and from the distribution of these animals, there is an apparent sub-division of the population into at least three sub-populations. Population estimates, using three different methods, shows the total New Zealand population of orca is at a critically low level (range 65-167 animals, with 115 calculated as alive in 1997). Based on the management of orca in Canada and the United States of America, and of other animals in New Zealand, there is a need to designate a conservation status for New Zealand orca that recognises their threats and low population levels.

Introduction

It is now commonly accepted that New Zealand is facing a major biodiversity crisis (Anon. 1998). With over 1000 individual taxa at risk, management of species and habitats is paramount in order for this to be halted. To manage on a species level, the unit for conservation managers has become the population (Dumbell 1987, Towns and Williams 1993). Hence, for effective biodiversity management of any species, agencies require basic information about the population (Lawton 1997).

A population can be defined as any group or groups of conspecifics within a given geographic area, that may or may not interbreed. A meta-population can be defined as the total of all populations (Craig 1994), or a population of populations (Hanski and Gilpin 1991). The level of interbreeding between populations is usually unknown and often will not be resolved until the genetic diversity is examined. While individual populations are often linked into a meta-population, managers typically deal with the local populations (sometimes referred to as sub-populations) as individual units. One example is the Hector's dolphin (*Cephalorhynchus hectori*), which is endemic to New Zealand waters (Dawson and Slooten 1988). This species has recently been identified as having four genetically distinct populations (Pichler and Baker 1999, Pichler *et al.* 1998), each found in geographically distinct areas around the country.

There is a need for management to understand population structure and potential sub-divisions, as it may be necessary to manage different populations or sub-populations individually. Again, using Hector's dolphin as an example, it could be conserved as a species by sustaining the population found along the east coast of the South Island. However, recent data on the minimal size of the North Island population (Russell 1999) highlights this type of scenario, as of the four apparently distinct populations, the North Island population has declined to levels where it is at high risk.

While considerable genetic variation for this species is already lost, total loss of the North Island population will markedly reduce genetic variance (Pichler and Baker 1999, Russell 1999). Moreover, from a social perspective, North Island people will be deprived of yet more of their biodiversity.

To gain information on a species or population, scientists employ a wide range of tools. Some methods require the researcher to identify individual animals. The use of tags for marking animals is being replaced by the ability to recognise individuals by their natural markings (Martin and Bateson 1986). These markings, and those resulting from injury, have been used to identify individuals from a wide range of species, including zebra (Schaller 1972), lions (Schaller 1972), fish (G. Jones, pers. comm.), crayfish (MacDiarmid 1987), chimpanzees (Goodall 1991), gorillas (Fossey 1974), elephants (Douglas-Hamilton 1973, Moss 1988), and cetaceans (whales, dolphins and porpoises) (Hammond *et al.* 1990b), including orca (*Orcinus orca*) (Bigg 1982).

Identifying animals by these naturally occurring features can be difficult and requires patience and practice, however, it is often the best approach in terms of minimising suffering and disruption to the animal (Pennycuick 1978). One way of keeping track of markings on an individual is photography, hence this method is commonly referred to as 'photo-identification' or 'photo-id'.

In New Zealand, photo-id work has previously been used on bottlenose dolphins (*Tursiops truncatus*) (Schneider 1999), the only endemic dolphin - Hector's dolphin (Dawson and Slooten 1988), southern right whales (*Eubalaena australis*) (Childerhouse and Donoghue 1999) and sperm whales (*Physeter macrocephalus*) (Childerhouse and Dawson 1996, Dawson *et al.* 1995). Overseas, photo-id methods have become standard practice for researchers working with orca (Bigg *et al.* 1987, Ford and Ellis 1999, Ford *et al.* 1994, Matkin *et al.* 1999), and have been used with confidence for a number of years, even using photos of the animals that were not originally taken for identification purposes (Ford *et al.* 1994, Matkin *et al.* 1999, von Ziegesar *et al.* 1986).

Studies of orca along the USA and Canada Northwest Pacific seaboard (PNW) have found the existence of three separate populations in the same area, and these now have distinctive conservation classifications (Baird 1999). Whether New Zealand orca are a single population, or are comprised of distinct sub-populations, is unknown. To date, little information about orca in New Zealand waters has been published (Baker 1972, Gaskin 1968, Hector 1875, Oliver 1922). Given this lack of historic and current data, research was instigated to establish the number of orca found in New Zealand waters, their distribution, and possible migrations and home range. As no other research projects in Australasia or the South Pacific deal with orca, the results presented here provide the only detailed data for this species in the area, and provide baseline information needed for effective management of orca within New Zealand waters.

Methods

The study area covered the coast of New Zealand out to approximately 20 miles offshore and included the offshore island groups; the Kermadecs, Three Kings, Chathams, Antipodes, Snares, Auckland and Campbell.

Sighting Information

Three main sources of data were used; 'Historic', 'Public', and 'Research'.

'Historic' sightings occurred prior to December 1992. The information was gathered from early records, including scientific articles, newspaper and video archives, records collected by agencies such as the Department of Conservation, the New Zealand Whale and Dolphin Stranding Database held at Te Papa (Museum of New Zealand), Project Jonah (a whale conservation group) records, and records collected by private organisations and persons. Data collected from this source included information such as date and location of animals, and in some cases included the estimated number of animals, general direction of travel, behaviour and photo-identification of some individuals. However, not all information was used (see Quality of Information, below).

'Public' sightings occurred after December 1992 and were gathered from the general public, sea faring people such as divers, fishers, whale and dolphin watching companies and Coast Guard. Data collected from this source included information such as date and location of animals, and in some cases included the estimated number of animals, general direction of travel, behaviour and photographs or videos. Again, not all information was used (see Quality of Information, below).

'Research' data was gathered in an opportunistic manner by the author from December 1992 until December 1997. Both a 4.3 m rigid hull inflatable with a 60 hp outboard, and a 5.8 m rigid hull inflatable with two 50 hp outboards were used as the main observation platforms. Occasionally other boats of varying sizes were utilised. Orca were encountered by chance or after a sighting was reported to a toll free number (0800 SEE ORCA). Once located the orca were followed until such constraints as fuel, weather conditions, or the animals' behaviour caused the encounter to be terminated. Details collected during an encounter included; date of sighting, location (recorded from nautical charts and/or a hand-held Global Positioning System), depth, number of animals present, direction of travel, behaviour, and photographs of individuals (see Photo Identification, below). All information was recorded, with time codes, onto a micro cassette recorder. These data were later transcribed and entered into Microsoft Excel ® spreadsheets.

For the purposes of this thesis, 'Researcher Effort' included time out on the water, time with the animals (see Results for details) and is also defined as the effort made to inform the public that orca reports were required, and making requests to the public for historic data, current photographs and videos. Researcher Effort incorporated the standard research method, Photo Identification (outlined below), and other aspects such as distributing posters and stickers, conducting talks and lectures, establishing a toll-free number, radio advertising, TV interviews, and newspaper and magazine articles etc. In order to compare Sighting Information with Researcher Effort, 'Researcher Days' are estimated. These are defined as days spent by the author in any Region (see below), with the exception of Region One – where Researcher Days were calculated based on five days/week (as the author lived in the area and not all days were 'on-effort'). In addition, time was spent either at offshore islands (and therefore were not in any of the six Regions) or outside of New Zealand waters (e.g., in Antarctica). In addition, for the purpose of this thesis, all sightings or records of orca used for analysis, regardless of origin (i.e., 'Historic', 'Public' or 'Research'), are defined as a 'report'.

Quality of Information

The quality of information from 'Historic' and 'Public' sources had the potential to vary widely. A subjective scale was devised, where reports were graded (Table 2.1). Both the source, as well as the actual data presented were graded, with 5/5 being the highest grade (see Table 2.1 for examples). As most members of the public could identify an orca (Chapter 1), very few reports were graded as a '1' in terms of source, but may have been graded as a '1' due to lack of substantiating evidence. In some cases, a Source 2 may have been upgraded to a Source 3 when two or more reports were made for the same location over a short period of time (e.g., within an hour). Source and Data grades used for this study are shown in Table (2.2). Information about the sighting supplied by the public (e.g., behavioural observations, group size and direction of travel) were not used for analysis.

Table 2.1.

Subjective scale used to classify information received from 'Historic' and 'Public' Sources.

Grade	Source
5	Reputable Source e.g., May be a whale-watch boat skipper, another cetacean researcher, or ferry skipper etc. Typically spends a lot of time on the water.
4	Good Source e.g., May have sent in photos of orca before, or has had experience with the animals in the past.
3	Fair Source Member of the public, offers information about the species that clearly identifies them, e.g., large dorsal fin, white eye patch.
2	Subjectable Source Member of the public that answers questions about the sighting but is unsure about some aspects, e.g., may not have seen an adult male, so can not make comment about large dorsal fins.
1	Doubtful Source Member of the public who was unsure of identification of species, e.g., may have made the comment 'I don't know, perhaps they are dolphins ?'

Grade	Data
5	High Clear sharp photos/video, where animals are identifiable as individuals. Accurately recorded Date, Location, Time etc.
4	Good Photos/video that clearly show the animals to be orca. No identification of individuals possible. Accurately recorded Date, Location, Time etc.
3	Fair Far off, out of focus photos/video, species identifiable. Accurately recorded Date, Location, Time etc.
2	Poor Out of focus photos/video, no species identification possible, or, no accurate date or location.
1	None No photographs or video.

Table 2.2. 'Historic' and 'Public' Source/Data combinations used for this study

Data / Source	5 (High)	4 (Good)	3 (Fair)	2 (Poor)	1 (None)
5 (Reputable)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
4 (Good)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
3 (Fair)	**Yes**	**Yes**	**Yes**	**No**	**No**
2 (Subjectable)	**Yes**	**Yes**	**Yes**	**No**	**No**
1 (Doubtful)	**No**	**No**	**No**	**No**	**No**

Regional Areas

The coastline of the main New Zealand islands is 15,650 km long (Statistics 1997), and for the purpose of this study, was divided into six Regions. Each Region was chosen as an area that appeared to have a clear boundary, either geographically (e.g., the west coast or east coast of the South Island), or due to a 'gap' in the reported sightings (e.g., the south-east coast of the North Island contains few sightings compared to the Coromandel Peninsula and further north). The six Regions (Fig. 2.1) are as follows: Region One (east coast, northern half of the North Island, i.e., Northland, Hauraki Gulf, Coromandel Peninsula); Region Two (east coast, southern half of the North Island, i.e., down to, but not including Wellington); Region Three (west coast North Island, north of the Manawatu River); Region Four (southern west and east coasts of the North Island, including Wellington, and northern section of the South Island including the Marlborough Sounds, and the east coast as far south as, and including Kaikoura); Region Five (east coast South Island, south of Cheviot); and Region Six (west and south coast of the South Island, and Stewart Island). Offshore Islands were not designated a Region due to the small number of sightings involved (see Results), the lack of resightings and the large area of sea involved in their widespread distribution.

Figure 2.1. Regional divisons of study area (boundaries do not reflect coverage area out to sea).

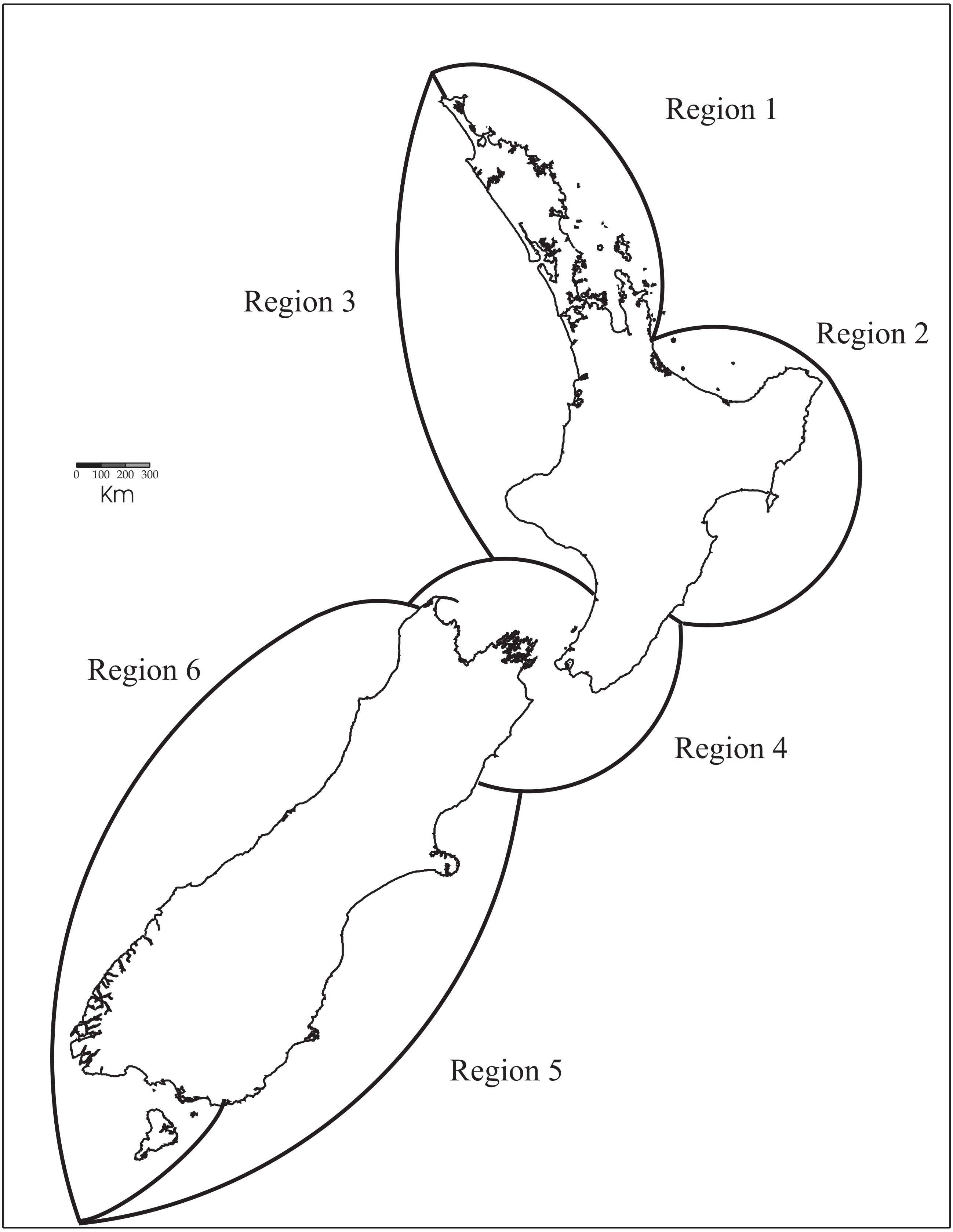


Photo Identification (Photo-id)

Photo-id is a method that utilises photographs to record congenital and acquired identification marks. For orca, every individual can be uniquely identified from high-quality photographs (Baird 2000). The dorsal fin is the main feature that is photographed because it is exposed above water more often than other areas (Bigg 1982). However, orca can also be photo-identified by their distinctive saddle patches (Baird and Stacey 1988, Bigg 1982), eye patches (Visser and Mäkeläinen 2000), pigmentation patterns on the underside of the tail (Fig. 2.2), malformations (Berghan and Visser 2000), scars from propellers (Visser 1999a, Visser and Fertl 2000) and body scars such as teeth rake marks (Fig. 2.2) and (Baird 2000, Visser 1998). In all cases where tooth rake marks were used and appeared as a contrasting colour (i.e., black on white, grey on black, or white on black), the marks have lasted for the duration of the study (i.e., at least six years) (e.g., Fig. 2.2). All orca photographed with high quality images in New Zealand were able to be positively (and uniquely) identified.

Figure 2.2. Pigmentation pattern and teeth rake marks that have remained visible on the underside of the tail of NZ6 during the period 1992 - 1997.

Although each individual can be uniquely identified, some animals have more distinctive marks than others. Scoring methods, to assess if biases exist for these distinctive (or non-distinctive) marks, have been used by other researchers using photo-id (e.g., Defran *et al.* 1999, Slooten *et al.* 1992) and a similar system was used for this study. All orca were scored on how marked their dorsal fin was. The scoring ranged from 0 – 5, with 5 being a distinctive fin, such as one with a deformity (e.g., Visser 1998). A score of 1 indicated that the animal was difficult to identify, but still had unique features. Overall, animals that were very distinctively marked (Grade 4 or 5) were not photographed more often than animals that were moderately marked (Grade 2 or 3) (for examples see below). Even so, some individuals (e.g., NZ15, Fig. 2.19) had such characteristic fins that it is possible they could have been photographed more often than others, or matches made from any angle (e.g., front-on or from behind). This would produce the equivalent of "trap addiction" in trapping studies (Moller and Craig 1987) and could marginally bias population estimates.

Therefore, the use of images from side-on only, were used to minimise this bias. In addition, the quality of the photograph was graded. For this, a score of '0' indicated that a clear sharp picture of the animal had not been obtained, a score of '1' indicated a clear sharp picture in which less than ½ the frame was filled, and a score of '2' indicated a clear sharp picture where more than ½ the frame was filled, and a score of '3' indicated a clear sharp picture where the dorsal fin was full frame. Only photographs of '2' or '3' quality were used for analysis.

The practice of taking photos of only one side of a dorsal fin is a standard technique for the orca populations of the PNW (Ford and Ellis 1999, Ford *et al.* 1994) and those commonly encountered in Norway (T. Similä, pers. comm.). Nevertheless, wherever possible during this study, both sides of the orca were photographed, as pigmentation patterns may differ considerably on each side of an animal (Leatherwood *et al.* 1984, Visser and Mäkeläinen 2000). Photographs of both sides of an orca may also improve the chances of subsequent rematches and allow photos from the public (which may have been of either side of an animal) to be matched.

During this study, photographs were taken using a Nikon F90x camera with a 80-200 (2.8 *f*) lens and Kodak 100 iso transparency film. Photos were printed and archived on an 'ID-card' with information such as the identity of the orca, date of encounter, location, estimated number of animals present, other photo-identified animals present, general behavioural information, and the photographer also recorded. As both missed matches and mis-matches can bias results (Gunnlaugsson and Sigurjónsson 1990), all images were checked by an independent cetacean researcher before analysis (less than 1% were incorrect).

To catalogue the orca, each animal was assigned a unique number preceded by the letters NZ, signifying that it was identified in New Zealand waters. The number indicated the individual animal but had no other significant meaning. Many of the orca were also assigned names that reflected a physical feature, indicated a location where they were sighted, a person they were photographed by, or a type of behaviour they were associated with.

Sighting data of individually identifiable animals came exclusively from photographs, not from individuals recognised in the field without being photographed, following Slooten *et al.* (1992) and Wilson *et al.* (1999). During a 'Research' encounter, attempts were made to photograph all orca present in a manner that was random with respect to identity. Individual animals may show differences in boat avoidance or approaches (e.g., see Fig. 5.2), or surfacing rates (Whitehead 1996). To minimise this potential bias, data collection protocol dictated that attempts were made to photograph all animals whenever they surfaced (avoiding preferentially photographing any particular individual). Typically during an encounter, multiple photos were obtained for each individual. Such conservative techniques ensure total accuracy and equal treatment of all sightings, as well as avoiding biases that may occur through "heterogeneity of capture" (Wilson *et al.* 1999).

The information from the photo-id techniques was used to identify the distribution and range of individual orca and general distribution trends for the population. This information was then used to assess if there were potential sub-populations, perhaps divided geographically.

Frequency of Resightings

If an individual is not resighted, it does not necessarily imply that it has died. Slooten *et. al.* (1992) offer four other possibilities: The individual could have;

1. Moved away from the study area temporarily or permanently
2. Been in the area but not been encountered
3. Been encountered, but not photographed
4. Not been identifiable from the photographs taken

It should be noted that #4 may include a photograph that was of poor quality, or the identifying marks on the animal have been obscured or removed by new marks, or, as is especially the case for subadult male orca, the dorsal fin shape may have changed considerably (i.e., 'sprouted', as the animal approaches sexual maturity), thereby preventing matching of photographs.

In other study areas around the world, some individual orca have not been resighted for up to 10 years, whereas others are seen numerous times each year (e.g., Baird 2000, Ford and Ellis 1999, Ford *et al.* 1994). As orca can live for up to 80 years (Bigg 1982), the potential is high for all of the four possibilities outlined above to feature in the resighting history of any individual.

Population Estimates

A population estimate is calculated using known values, such as the number of animals that have been identified and the number of resightings. A simple cumulative total was used (Discovery

Curve) and calculations for the Total Enumeration (TE) and a stochastic model (Jolly-Seber) were both used for estimating the population of New Zealand orca.

Discovery Curve

The Discovery Curve plots the cumulative total of uniquely identified individuals. This method does not provide a true population estimate as it does not take mortality into account.

Total Enumeration (TE)

The 'Total Enumeration' (TE) incorporates the addition of all individuals seen prior to, and including the last sample period, devalued by the likely mortality rate. The mortality rate for New Zealand orca is not known, therefore the estimate of annual mortality of 2% was used from the PNW study of orca (Olesiuk *et al.* 1990). The TE method is based on individuals photo-identified, and provides a conservative underestimate of minimum population size (Hammond *et al.* 1990a). It is a conservative technique that avoids the biases that inevitably result from violation of the assumptions of population models. The Total Enumeration was calculated for December 1997.

Jolly-Seber Population Model

A basic population model suitable for a population that is assumed to be open to additions (e.g., births and immigration) and permanent deletions (e.g., deaths and emigration) is the Jolly-Seber model (Jolly 1965, Seber 1965). This model assumes the following:

1. The orca population being investigated is an 'open population', i.e., it is subject to birth + immigration and death + emigration.
2. Every animal present in the population, at the time of the i^{th} sample (i = 1, 2,…, k), has the same probability of capture - (p_i) - whether this animal has been previously identified or not.
3. Every marked animal present in the population, immediately after the i^{th} sample, has the same probability of survival - ($Ø_i$) - until the $(i+1)^{th}$ sampling time (i = 1, 2,…, k-1).

4. Marks are not lost, nor overlooked and are correctly identified (i.e., "false positives", mis-matches and missed matches are not made).
5. Samples are instantaneous and releases are made immediately after the sample, i.e., sampling time is negligible and does not affect the calculation.

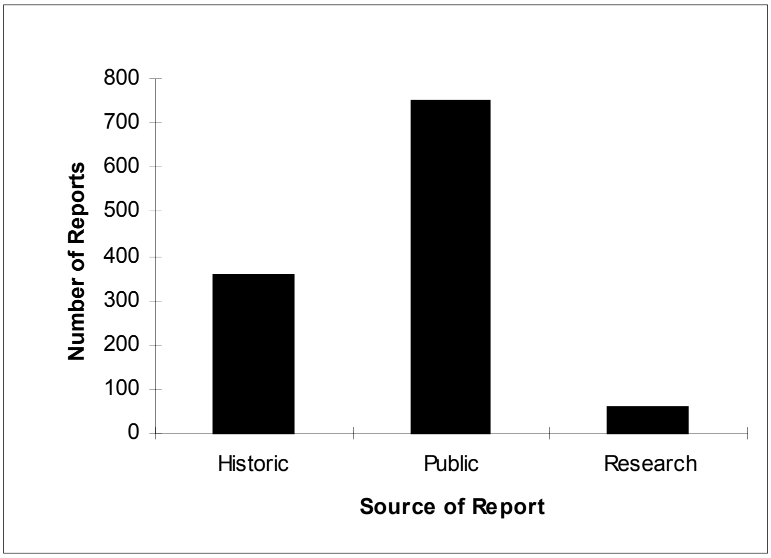
The Jolly-Seber model allows estimation of the population size at each sampling time. The validity of results can be affected by outliers, therefore the initial sample times (from historic data) which were far apart and sparse, were removed. Calculations were conducted utilising POPAN-4, a population analysis program based on the population model of Jolly-Seber (Arnason and Baniuk 1978, Arnason *et al.* 1992, Arnason and Schwarz 1995, Pollock *et al.* 1990). Monthly sightings were converted into the form required by POPAN-4 using SAS (a statistical computer program) (Arnason and Baniuk 1978). When sampling intensity is low or variable there can be difficulties with ensuring the robustness of data, e.g., that each animal has an equal probability of capture within the sampling period (Kreger 1973). Therefore, within POPAN-4 the data was further grouped into six-month periods for the analysis. This six-month period helps to reduce the potential errors from shorter sample times and was also chosen to validate the assumption of equal probability of capture. Orca are long-lived, and hence this longer sample period was used to increase the likelihood that any animal would have an equal probability of being resighted.

Results

Sighting Information

A total of 1069 orca sighting reports were collated. 'Historic' data accounted for approximately 27% of the total records of orca around the New Zealand coastline (Fig. 2.3). The data collected from the 'Public' accounted for approximately 66% and 'Research' 7% of the total records.

Figure 2.3. Orca reports collected from different sources: Historic, Public and Research (*n* = 1069).



A total of 16 reports came from off-shore island groups (Table 2.3). For 13 of these, no photographs were obtained. As these reports were widespread, both spatially and temporally, and did not come from a designated Regional area, they were not included in the total number of sightings reported, nor in any analysis. The Chatham Islands had the highest number of sightings for any of the off-shore island groups, comprising 57% (*n* = 8) of the offshore sightings. The remaining three off-shore reports were encounters with five orca (over three days) off the Three Kings Islands by the author, and photographs were taken. These five animals were included in analyses.

The earliest photograph collected of an orca was from 1915 (Fig. 2.4). In this instance, three orca entered Tauranga Harbour and were driven ashore and killed by local whalers. Although the two orca in the photo are identifiable, these animals were not included in the catalogue of 117 animals, as they were known to be dead at the start of the study.

Table 2.3. Distribution of Sightings of Orca from Offshore Island Groups (n = 16)

Island Group	# of Reports by public	# of Encounters by author
Campbell Islands	1*	
Kermadec Islands	1	
Three King Islands	4	3 §
Chatham Islands	8	
Snares Islands	2	
Auckland Islands	1	
Sub Total	13	3 §

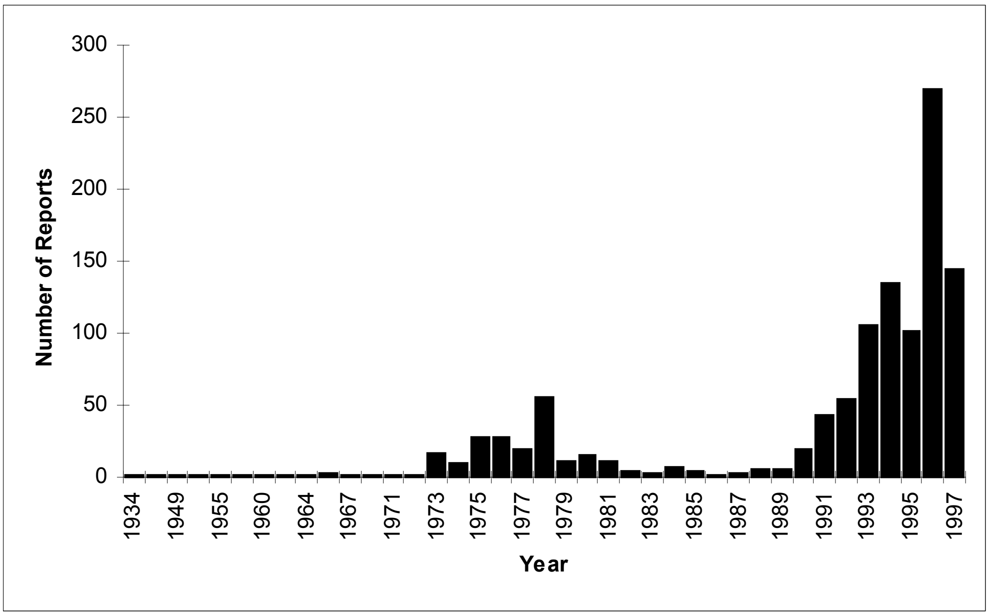
* published account, no date given but pre 1945 (Sorensen 1950)

§ published account, and the only off-shore records with photos (Visser, 2000)

Figure 2.4. Two of three orca killed and boiled down for oil, which was apparently of inferior quality. Tauranga Harbour (Auckland Mail, 1915).

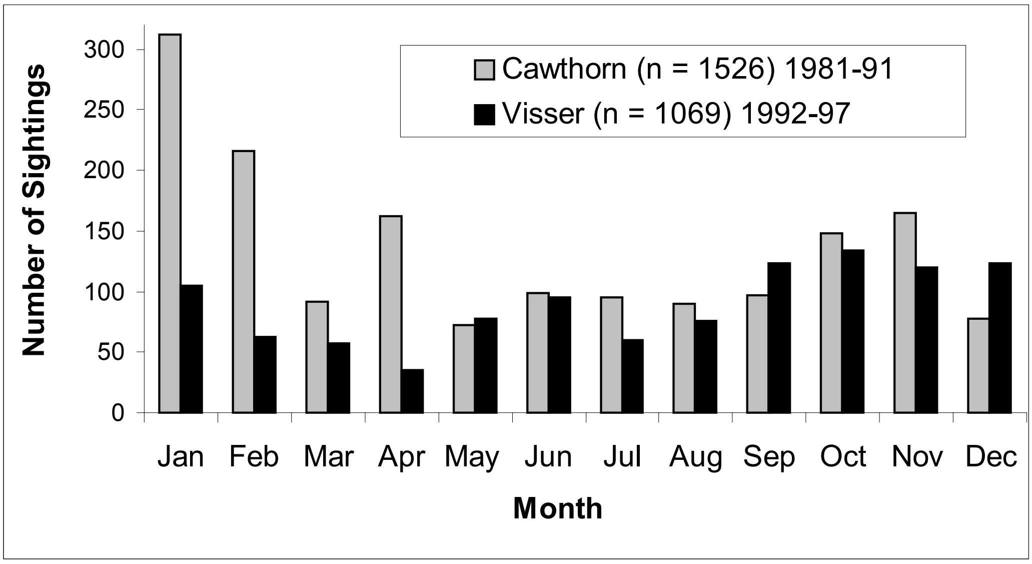
Overall, between 1934 – 1997, orca sightings were few prior to 1992 when this study began (Fig. 2.5). The decrease in reports for 1997 is a reflection of a decrease in Researcher Effort.

Figure 2.5 Distribution of Orca reports (1934-1997)



Between the years of 1981-1991, Cawthorn (1981, 1982, 1983, 1984, 1986, 1989, 1990, 1991, 1992) collected reports of cetacean sightings from aircraft, vessels at sea, and shore-based observers. Within these reports were 1526 records of orca sightings. However, the data were presented only as number of sightings per month, and no further details were given (e.g., number of orca present). Furthermore, the data origins were not reported, i.e., the actual location of the sightings are not apparent, nor even if the sightings were of North or South island origin. However, in some of these publications commercial whale watch companies and fishermen off Kaikoura are mentioned, suggesting that the data may be biased towards South Island reports. Cawthorn's data (10 year period) were plotted against the data collected for this study (five year period) (Fig. 2.6). Taking into consideration the greater number of sightings, Cawthorn's data appears to have more sightings per month for January - April, but overall (with the exception of April and December) reflects a similar monthly distribution to that found during this study.

Figure 2.6. Plot of data from Cawthorn (see text) vs. this study



Regional Areas

Although Region One had a high number of orca reports (Fig. 2.7a), and a high number of people living in the Region (Fig. 2.7b), the number of orca reports for each Region did not correlate with the number of people living in the area – Spearmans Rank correlation ($r_s = 0.59$, *df* = 5, p > 0.5). However, orca reports were correlated with the amount of Researcher Effort based on the number of Researcher Days spent in each Region (Fig. 2.7c) ($r_s = 0.95$, *df* = 5, p < 0.05), i.e., the more Researcher Effort devoted to each Region, the more reports were received. The Researcher Effort varied from Region to Region each year, but was highest in Region One and Region Four during the entire study period. It was considerably lower in the other regions, with Regions Three and Five receiving similar, but lower, effort. Region Six received the least amount of Researcher Effort except late in the study, during December 1996, when a lone orca calf was studied by the author. Overall, Region One had the highest number of reports (*n* = 569), with Region Six the lowest (*n* = 11) (Fig. 2.7a).

The monthly distribution of reports in each Region (from all sources) showed some trends. Reports in Region One (*n* = 569) peaked in September (Fig. 2.8a). Region Two (*n* = 190) showed a peak in reports during June and an increase from October until December, followed by a decline for January

(Fig. 2.8b). Region Three had a small number of reports (n = 38), with no reports for either August or September (Fig. 2.8c). Region Four (n = 247) showed the clearest trend, with a decrease in reports during the austral winter months (Fig. 2.8d). Region Five had a small number of reports (n = 14) with no reports for April – September and November (Fig. 2.8e). Region Six had the smallest number of reports (n = 11) and no trends were conspicuous (Fig. 2.8f). Overall, few real patterns emerged, except Region One (Fig. 2.8a) and Region Four (Fig. 2.8d) appear to reflect a shift in distribution (i.e., orca are more likely to be seen in Region One during September and October, and in Region Four during November to February).

Photo Identification

<u>Distribution and Range of Individual orca</u>

Ten orca 'sighting profiles', including their catalogue number (and name in brackets), are described below. The records for each animal were collected from the 'Historic' and 'Public' sources, as well as 'Research' encounters (the exception is NZ50, see below). In some cases, repeat sightings may have occurred in the same location in the same month, but were unique sightings, and have been listed as such.

These ten profiles were chosen because they represent frequently observed sighting patterns, or idiosyncratic ones. Sightings profiles of other orca are given in Visser (1999a) and Visser and Fertl (2000). There are three main patterns of distribution (Table 2.4), however, the sighting locations for individual orca may vary within each general trend.

Table 2.4. Distribution Types

Distribution Type	**Area Seen**	**Examples of this Distribution**
(i)	North-Island-only	Fig. 2.10, Fig. 2.12, Visser (1999a) and Visser and Fertl (2000.)
(ii)	North+South-Island	Fig. 2.14, Fig. 2.16, Fig. 2.18, Fig. 2.20, Fig. 2.22, Fig. 2.24, and Visser (1999a)
(iii)	South-Island-only	Fig. 2.26, Fig. 2.28

Figure 2.7. Distribution of orca reports, people and Researcher Effort, around the New Zealand coast, by Region (see Fig. 1 for details of regional divisions).

Figure 2.7a. Distribution of orca reports, by Region (n = 1069)

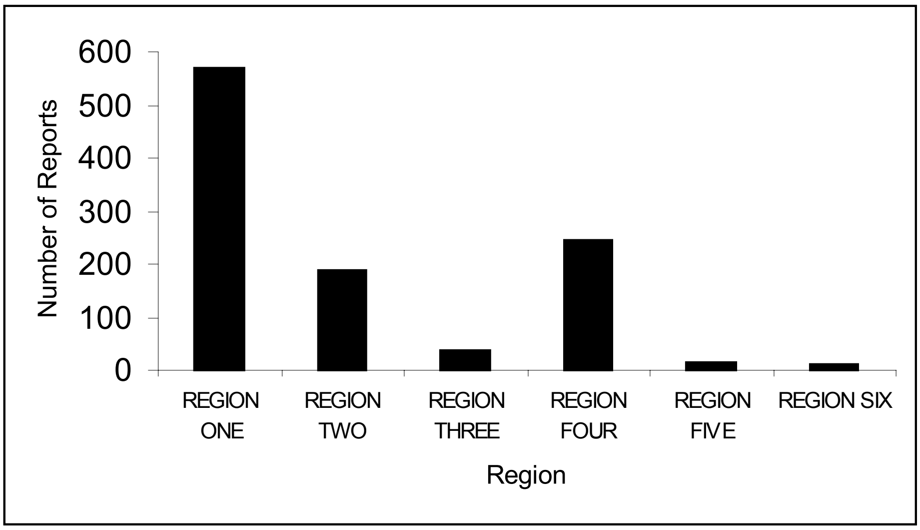


Figure 2.7b. Distribution of people (1997), by Region (n = 3395526) New Zealand Statistics (1997)

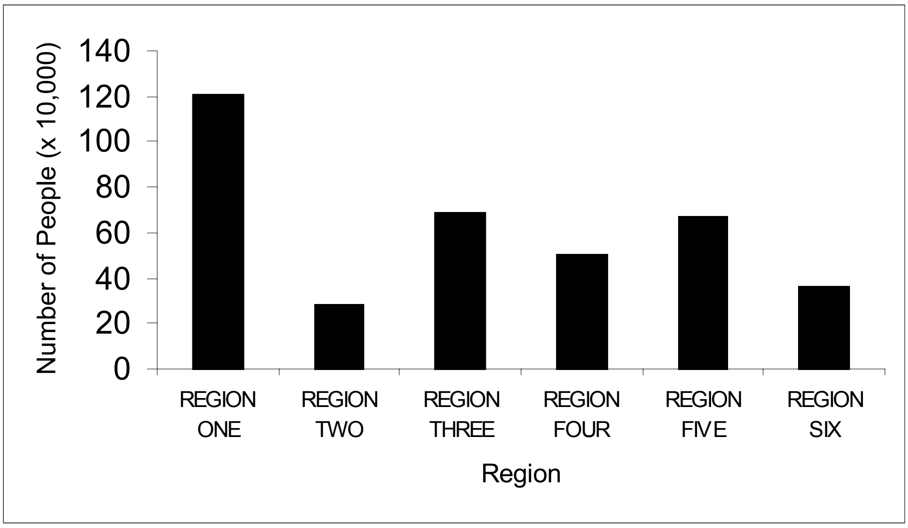


Figure 2.7c. Distribution of Researcher Effort (1992-1997), by Region (n = 1306)

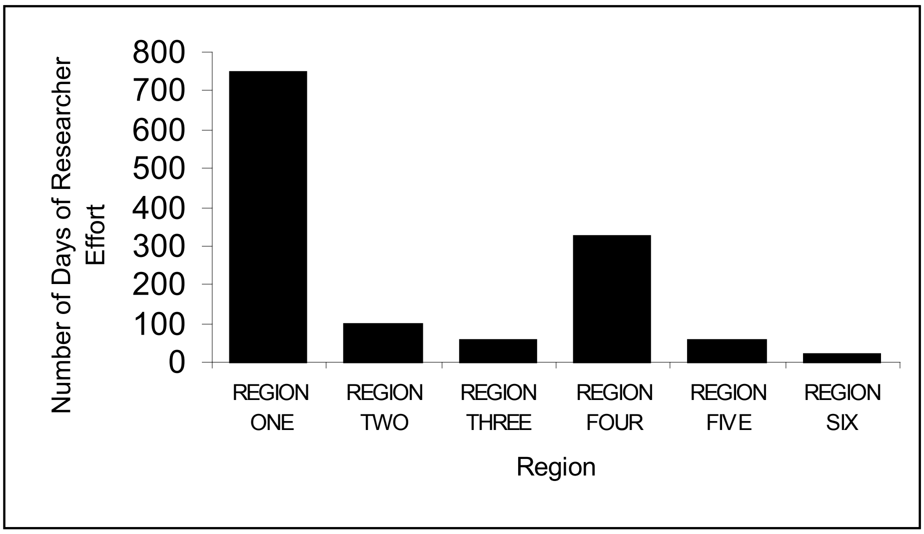
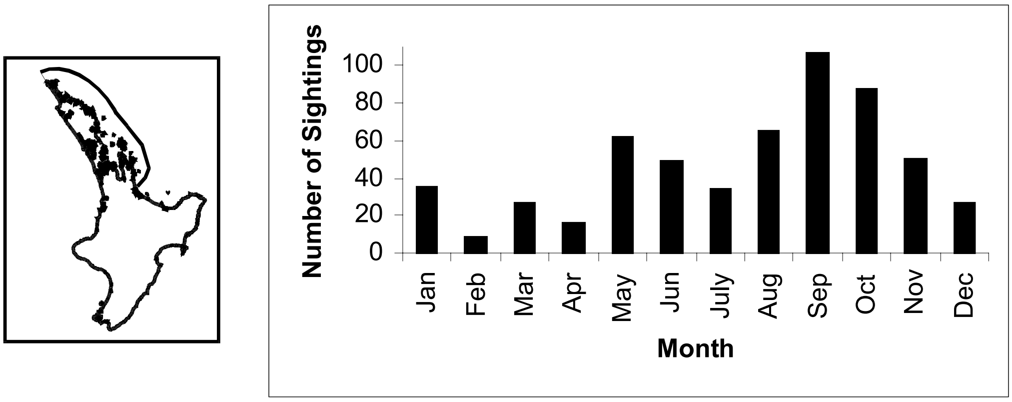
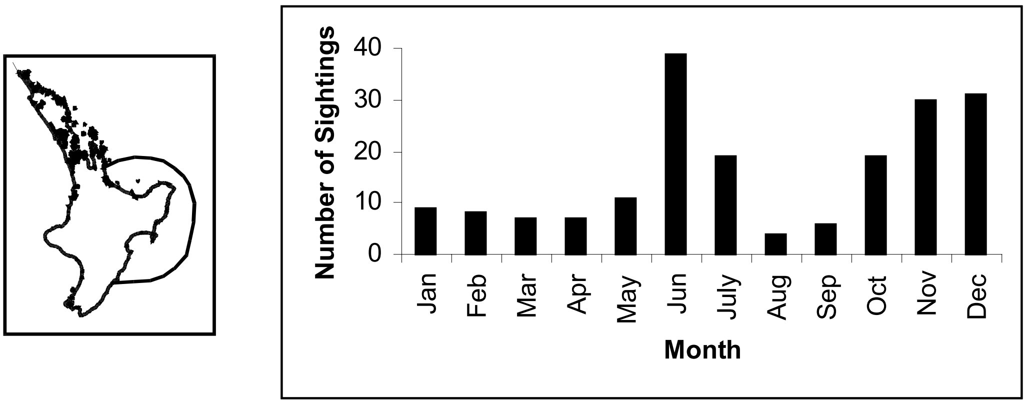


Figure 2.8. Sightings of orca, reported in each Region, by month.
(NOTE: Scale of 'y' axis is variable)

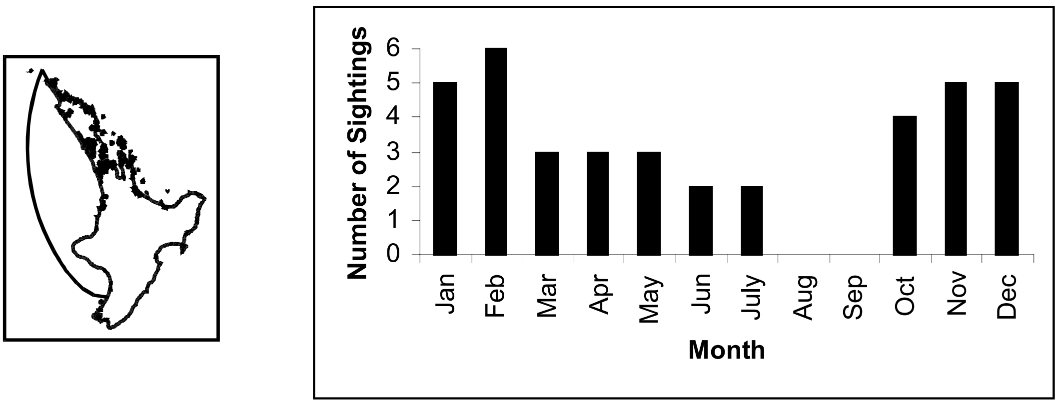
2.8a. Region One, orca reports by month (n = 569)



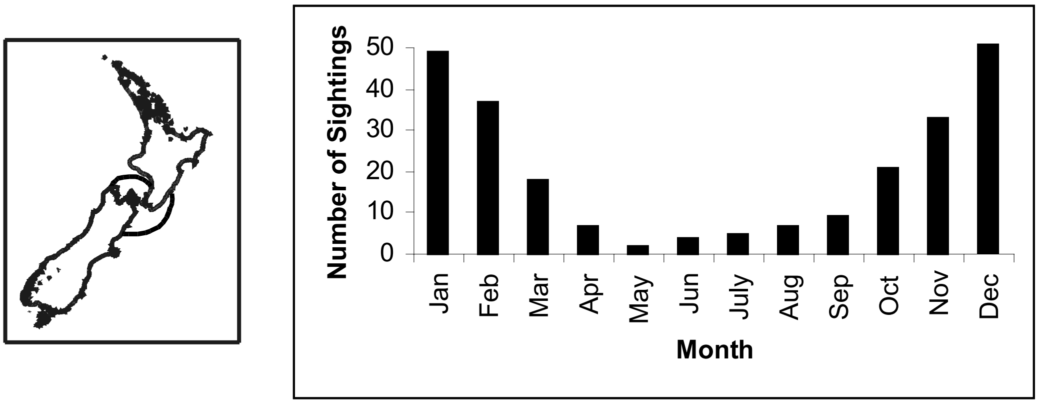
2.8b. Region Two, orca reports by month (n = 190)



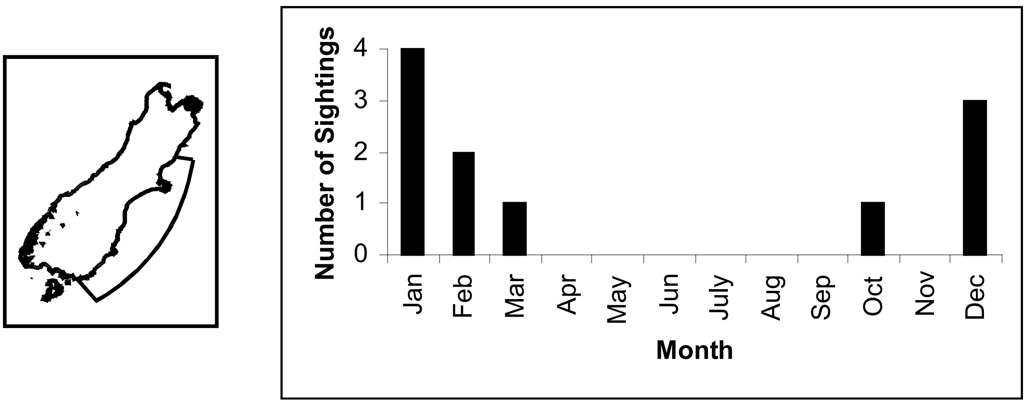
2.8c. Region Three, orca reports by month (n = 38)



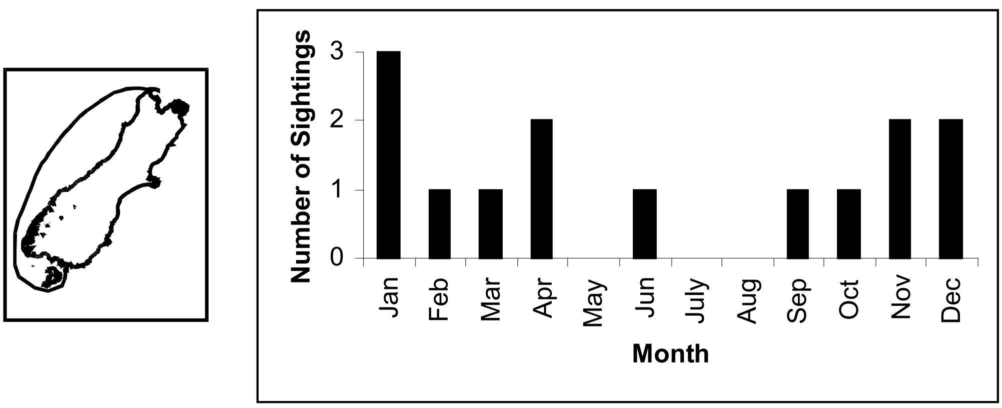
2.8d. Region Four, orca reports by month (n = 247)



2.8e. Region Five, orca reports by month (n =14)



2.8f. Region Six, orca reports by month (n =11)



Distribution Type (i) North-Island-only

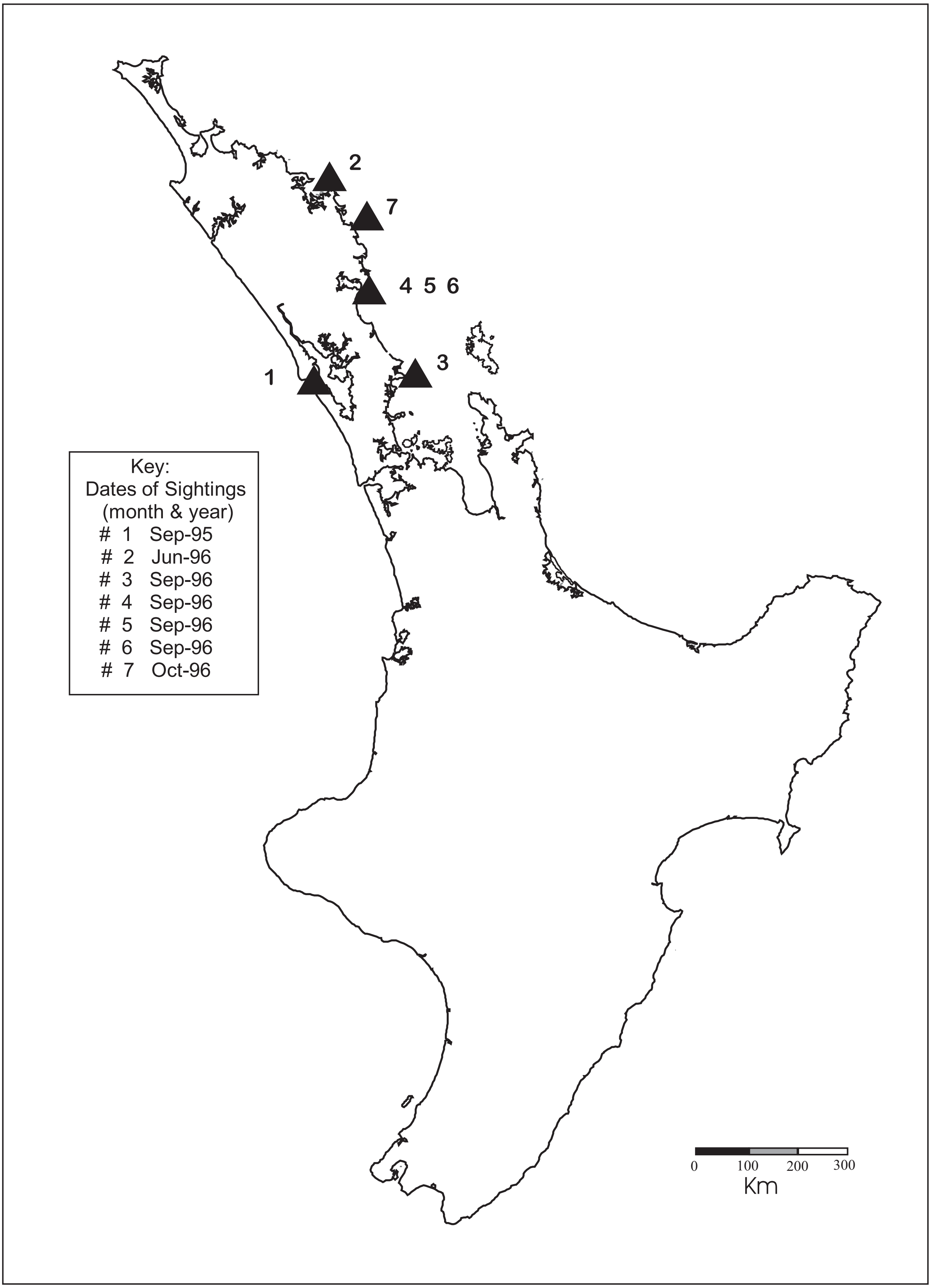
NZ50 ('Digit')

NZ50 is an adult female. 'Digit' is named after a mountain gorilla in the Virunga Mountains, Rwanda, who approached the researcher, Dian Fossey (Fossey 1983). 'Digit' the orca makes approaches to the research vessel and contact with the author (see section on Orca-Human interactions, Chapter Six). She has no easily distinguishable marks on her fin, which is classified as a Grade 1 (Fig. 2.9).

Figure 2.9. NZ50 ('Digit'). This female orca has minimal marks on her fin. (Grade 1).

NZ50 was first photographed in September 1995 in the Kaipara Harbour, North Island (sighting # 1, Fig. 2.10), and has been photographed on seven occasions during a two year period (1995 - 1996). Six of these sightings were on the east coast of the North Island. The minimum distance between the Kaipara Harbour (west coast) (sighting # 1, Fig. 2.10) and the Kawau Channel (east coast) (sighting # 3, Fig. 2.10) is 2100 km, assuming the shortest route around the northern tip of the island was taken. The collection of data for sightings for NZ50 are atypical in that all records (i.e., photographs) were collected by the author. Her distribution is similar to that of NZ63 (Fig. 2.12) except that NZ50 has also been photographed on the west coast, as has NZ101 (Visser and Fertl 2000) who also has a Type *(ii)* distribution.

Figure 2.10. Location of Sightings of NZ50 ('Digit') (n = 7) from 1995 - 1996



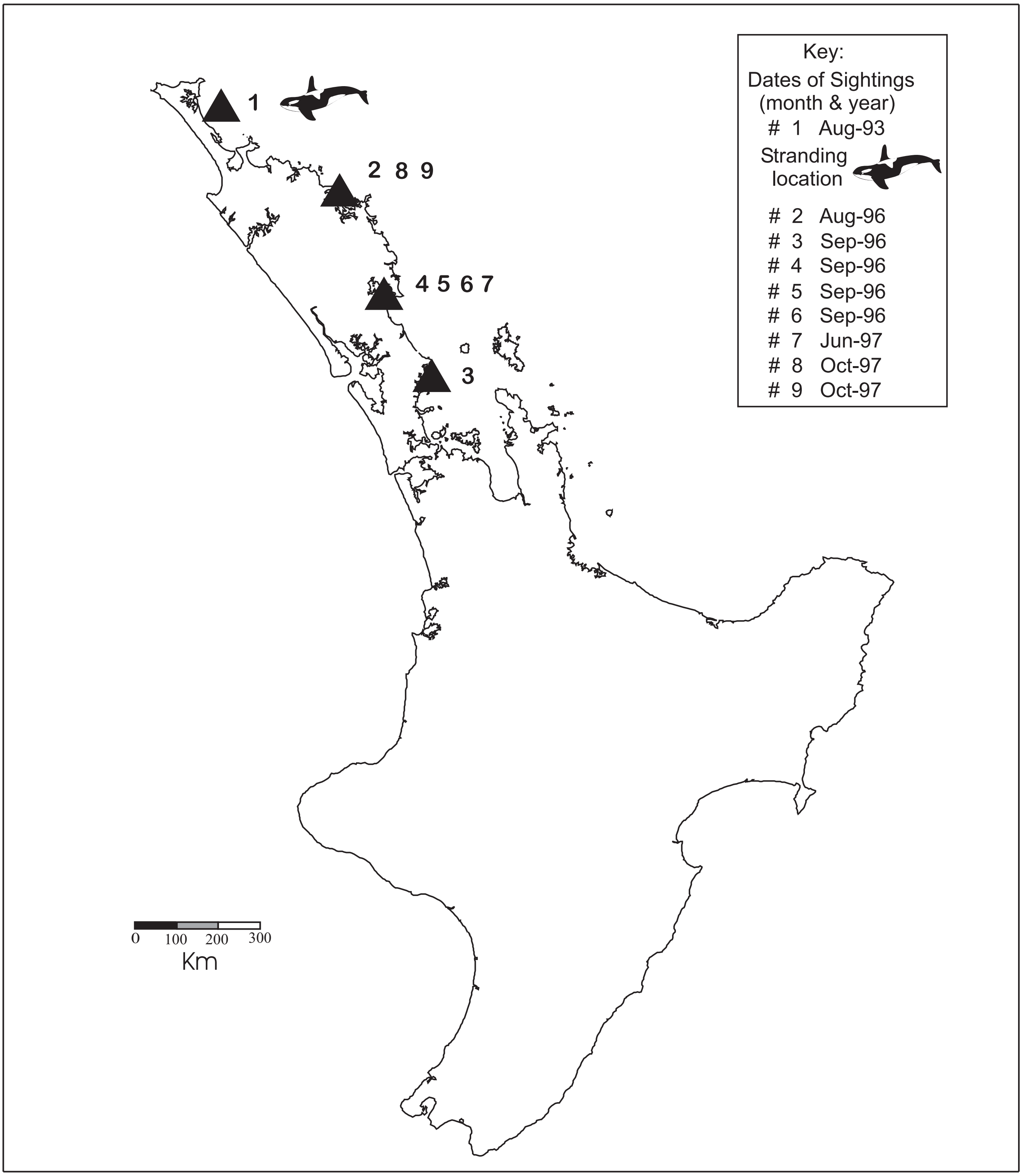
NZ63 ('Miracle')

NZ63 is an adult female. Her name, 'Miracle,' comes from the unlikely chance of her rescue and re-identification following her stranding at Great Exhibition Bay, Northland. Her dorsal fin is a Grade 3, with a small rounded notch out of the trailing edge (Fig. 2.11). NZ63 was first photographed in 1993 when she stranded. She is the most northern identified animal around mainland New Zealand.

Figure 2.11. NZ63 ('Miracle'). This female has a small rounded notch in the trailing edge of her fin (Grade 3).

NZ63 has been photographed nine times during a five year period (1993-1997). After the stranding she was not resighted again for three years (sighting # 2, Fig. 2.12). She has been seen as far south as Kawau Island, east coast (sighting # 3, Fig. 2.12), with the minimum distance between the stranding and Kawau Island being 590 km. Her distribution is similar to that of NZ50 (Fig. 2.10), except NZ63 has not been sighted off the west coast of the North Island.

Figure 2.12. Location of Sightings of NZ63 ('Miracle') (*n* = 9) from 1993 - 1997



Distribution Type (ii) North+South-Island

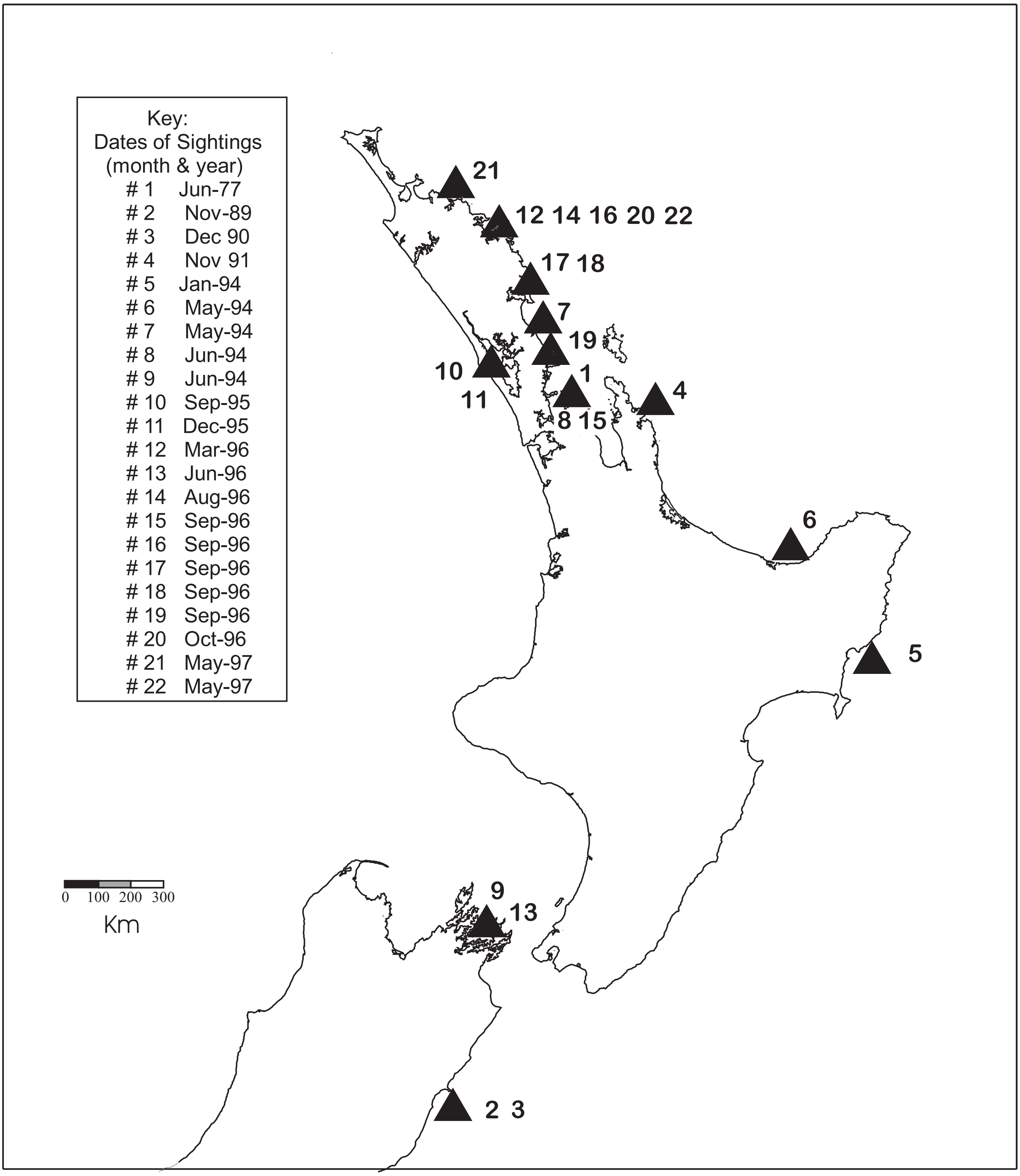
NZ1 ('A1')

NZ1 is an adult female. Her name 'A1' results from an early alphanumeric system of cataloguing groups of orca and individuals within the group. The 'A' stands for the first group catalogued, and the '1' indicates she was the first identified animal. She has the top of her fin missing, and from comparisons to similar mutilations (Norris 1992), it is assumed that she lost it from fishing line entanglement. This severed top gives her fin a Grade 5 classification (Fig. 2.13). NZ1 was first sighted in 1977 in the Auckland Harbour. She was already an adult with the top of her fin missing.

Figure 2.13. NZ1 ('A1'), has a severed fin, presumed to have been cut off with fishing line (Grade 5).

During the 20 year period (1977-1997) over which she has been photographed around the New Zealand coastline, NZ1 has been identified 22 times (Fig. 2.14). The farthest north she has been recorded is Doubtless Bay, Northland (sighting # 21, Fig. 2.14), and the farthest south is off the Kaikoura area, South Island (sightings # 2 & 3, Fig. 2.14). NZ1 has also been recorded in the Kaipara Harbour on the west coast of the North Island on two occasions (sightings # 10 & 11, Fig. 2.14). This animal has the widest distribution of any identified individual, and has been recorded in four Regions (Regions One, Two, Three & Four) over a 20 year period. The minimum distance that she has travelled between the northern and southernmost sightings is 4200 km. The distribution of sightings for NZ1 is similar to NZ6 (Fig. 2.16) and NZ7 (Fig. 2.18).

Figure 2.14. Location of Sightings of NZ1 ('A1') (*n* = 22) from 1977 - 1997



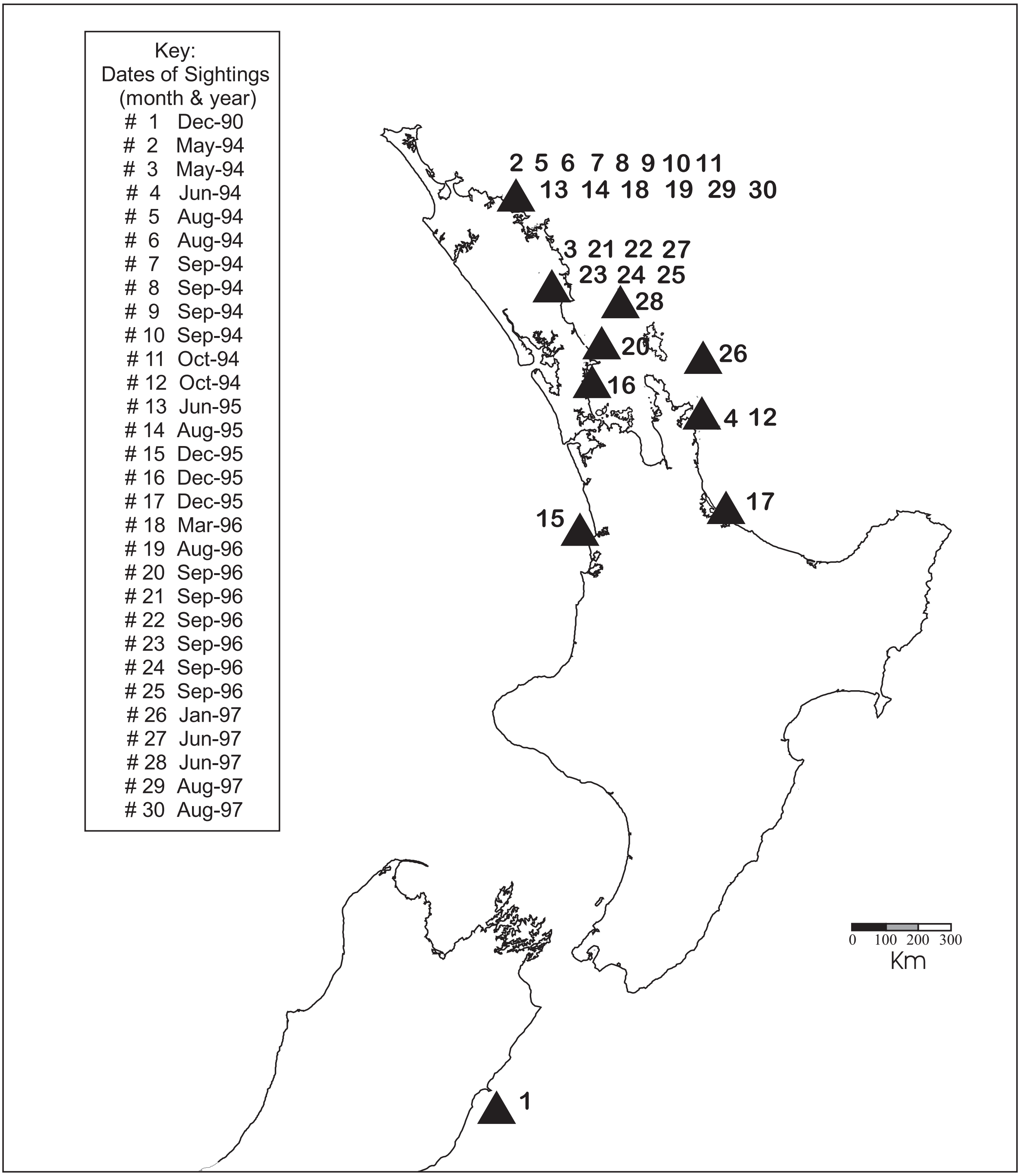
NZ6 ('Rocky')

NZ6 is an adult male. He gained his name 'Rocky' because of his method of hunting for stingrays amongst rocks. His fin is a Grade 1, but can be identified by the very broad base (Fig. 2.15). NZ6 was first photographed in December 1990 off Kaikoura, South Island.

Figure 2.15. NZ6 ('Rocky'). This dorsal fin has a broad base to height ratio, but has very few other distinguishing features (Grade 1)

NZ6 has been photographed around the New Zealand coastline on 30 occasions over a seven year period (1990 – 1997). The furthest north he has been recorded is the Bay of Islands, North Island, and the furthest south is off the Kaikoura area, South Island. He has also been recorded in the Raglan Harbour, west coast of North Island in 1995 (sighting # 15, Fig. 2.16). The minimum distance that NZ6 has travelled between the northern and southernmost sightings is 3900 km. The distribution of sightings for NZ6 is almost identical to that of NZ7 (see below). In addition, NZ6 has been photo-identified comparatively more often (n = 30) than other adult males (e.g., NZ7, n = 23; NZ15, n = 10; NZ23, n = 8; NZ26, n = 11).

Figure 2.16. Location of Sightings of NZ6 ('Rocky') (n = 30) from 1990 - 1997



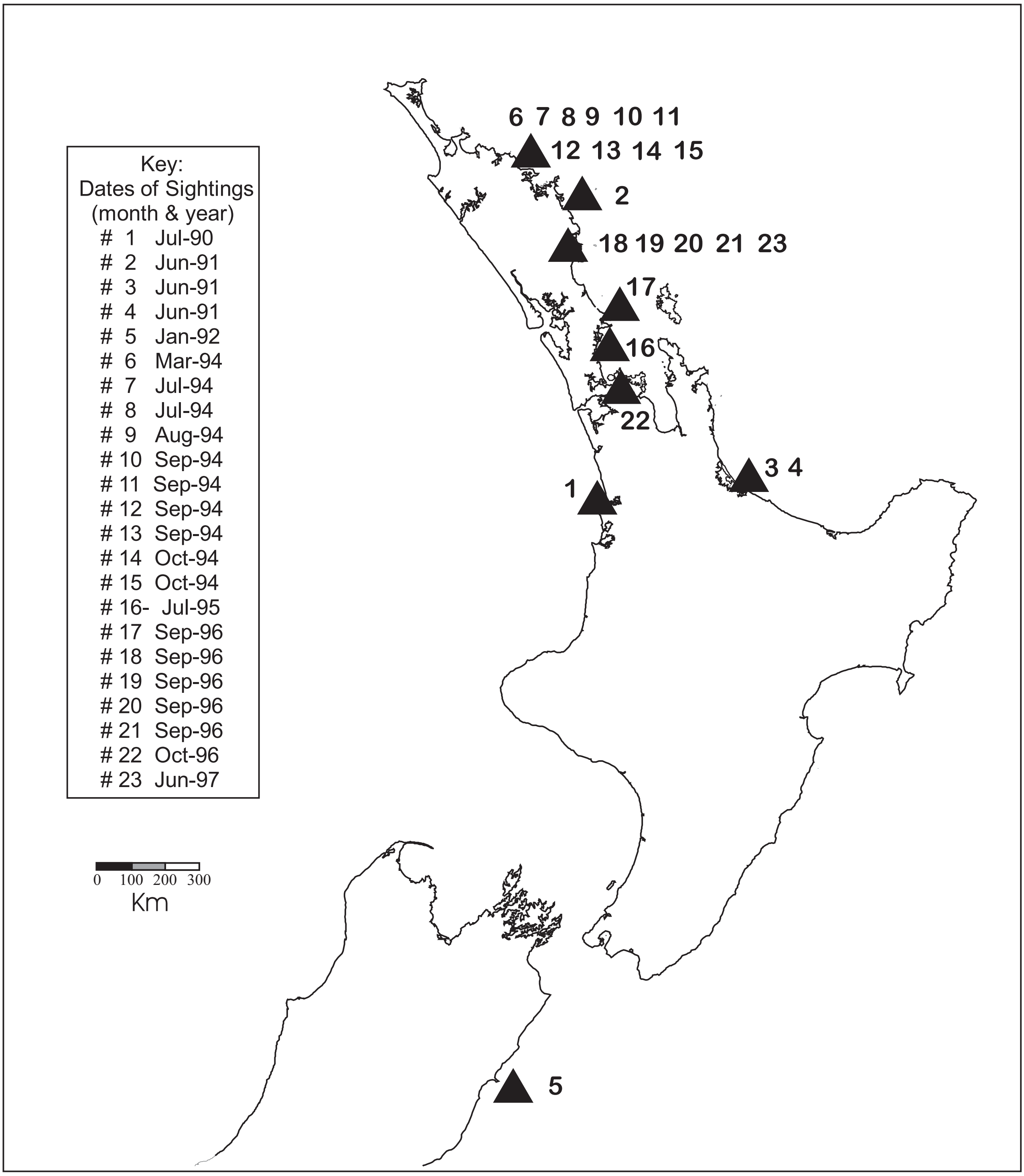
NZ7 ('Spike')

NZ7 is an adult male. He is named 'Spike' due to the 'spike-like' shape of his dorsal fin. He has no easily identifiable features, but has two dark parallel marks on his right saddle patch (Fig. 2.17), making his fin a Grade 1. He was first photographed in July 1990 off Raglan, west coast of the North Island.

Figure 2.17. NZ7 ('Spike'). Named after his 'spike' shaped dorsal fin. Note the two dark parallel marks on the saddle patch (Grade 1 fin).

'Spike' has been photographed around the New Zealand coastline on 23 occasions during a seven year period (1990 - 1997). The farthest north NZ7 has been recorded is the Bay of Islands, North Island, and the farthest south is off the Kaikoura coast, South Island. He has also been recorded in Raglan Harbour, on the west coast of the North Island (sighting # 1, Fig. 2.18). The minimum distance that he has travelled between the northern and southernmost sightings is 3900 km. The distribution of sightings for NZ7 are almost identical to that of NZ6 (Fig. 2.16).

Figure 2.18. Location of Sightings of NZ7 ('Spike') (*n* = 23) from 1990 - 1997



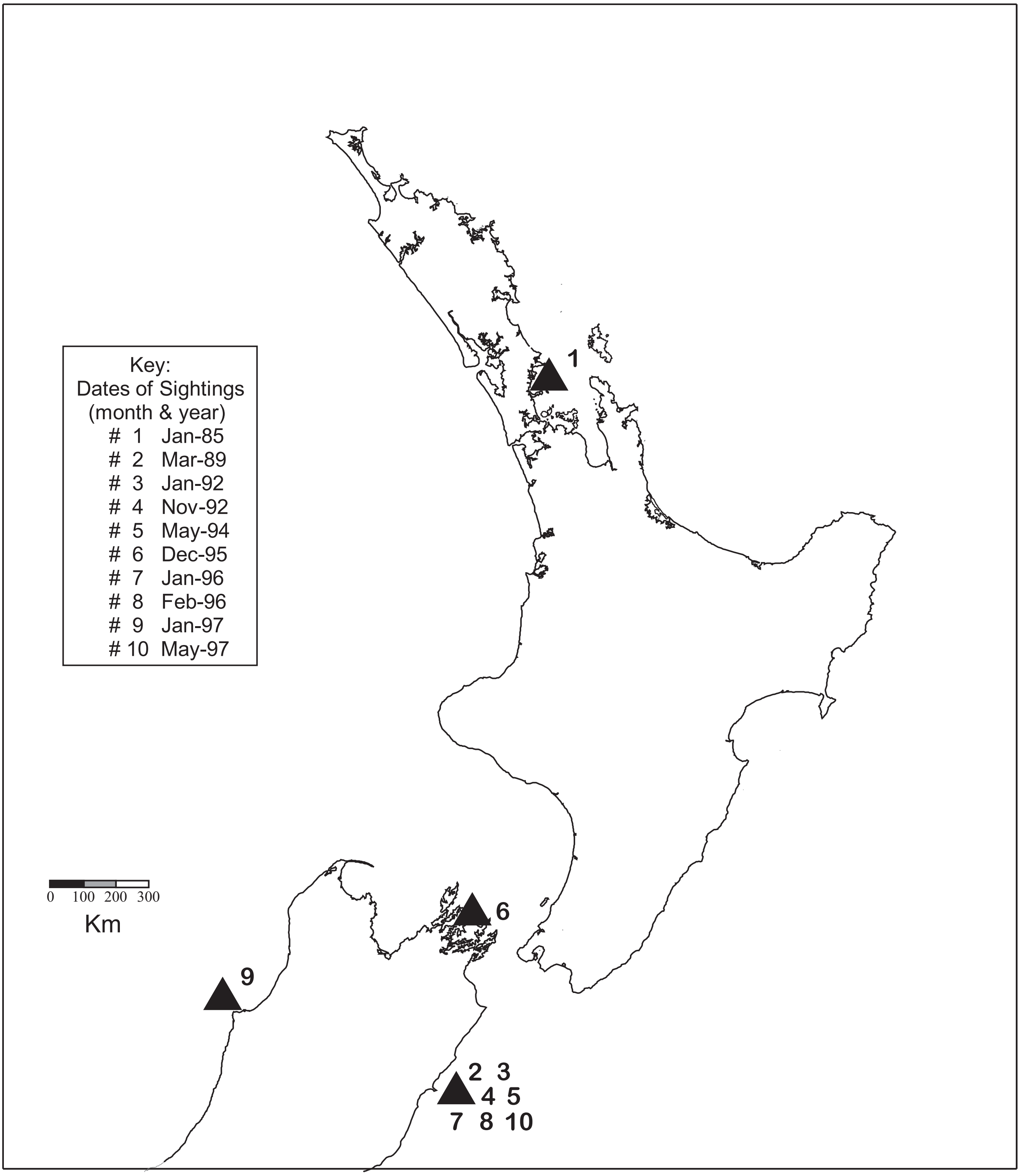
NZ15 ('Corkscrew')

NZ15 is an adult male. He is named 'Corkscrew' because his dorsal fin is bent to give the impression of a 'twist' (Fig. 2.19, and see Fig. 3 in Visser 1998). NZ15 is readily identifiable from at least 1 km distance and his fin is classified as a Grade 5. He was first photographed in 1985 in the Auckland Harbour.

Figure 2.19. NZ15 ('Corkscrew'). This dorsal fin is characterised by a distinctive 'twist' (Grade 5).
Photo: Compliments of S. Yin

NZ15 has been photographed around the New Zealand coastline ten times during a 12 year period (1985 - 1997). The farthest north that he has been recorded is the Auckland Harbour, North Island (sighting # 1, Fig. 2.20), which is the only sighting of him in the North Island. He has been photographed off the west coast of the South Island (sighting # 9, Fig. 2.20) on one occasion, and seven times off the East coast. He has also been sighted once off the Marlborough Sounds (sighting # 6, Fig. 2.20). The minimum distance between his northernmost (Auckland Harbour) and southernmost (Kaikoura) sighting is 4200 km. Although NZ15 has a Type *(ii)* distribution, the actual distribution of sightings is atypical, in that he is one of only two orca (both adult males) to be positively identified off the west coast of the South Island (see NZ23, Fig. 2.26). In addition, NZ15 has been seen nine times in the South Island and only once in the North Island (*cf* NZ6 who has been seen 29 times in the North Island and only once in the South Island, and NZ7 who has been seen 22 times in the North Island and only once in the South Island).

Figure 2.20. Location of Sightings of NZ15 ('Corkscrew') (*n* = 10) from 1985 - 1997



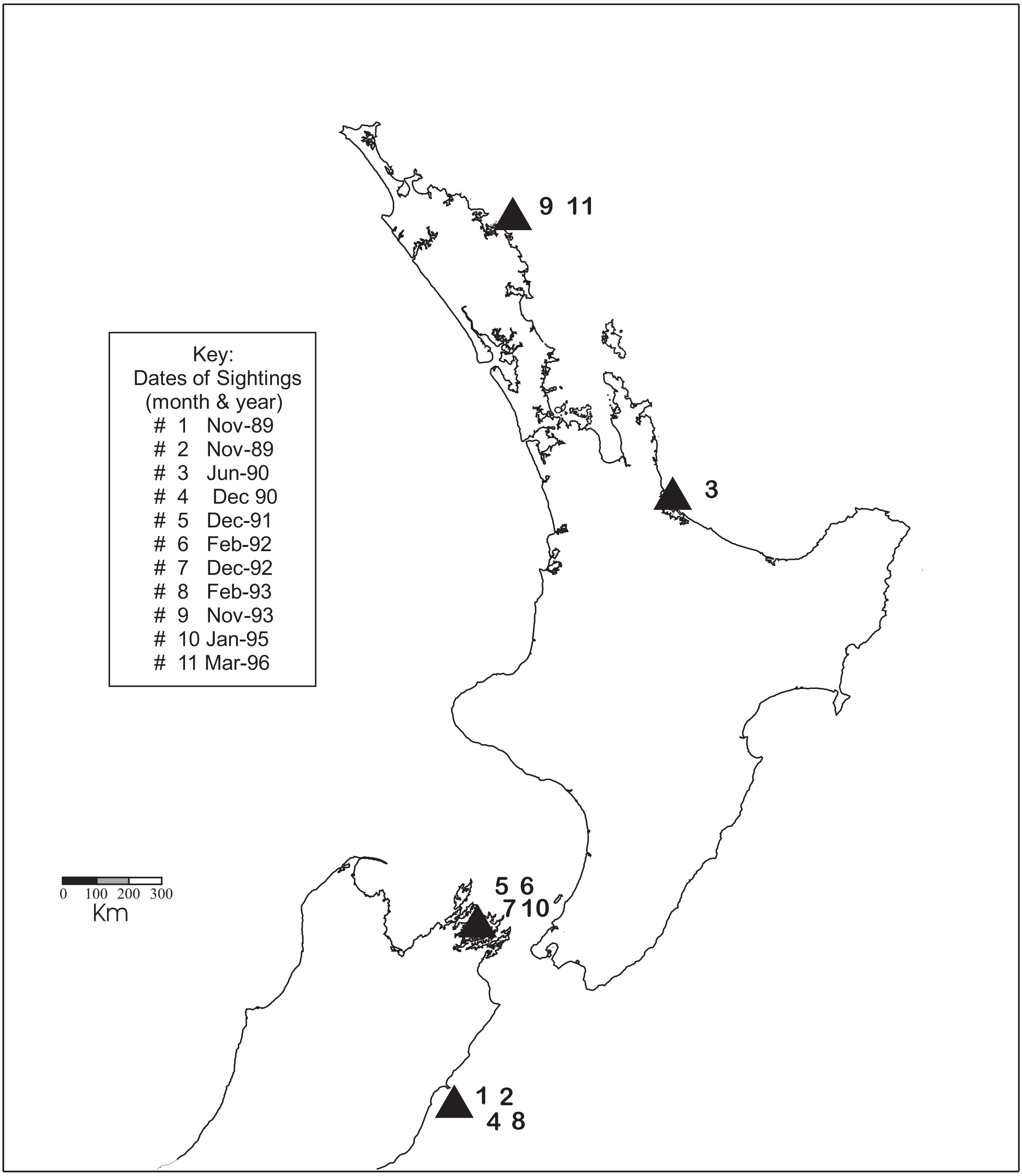
NZ26 ('Topnotch')

NZ26 is an adult male. He has a large notch out of the top of his fin, hence his name. NZ26 is one of seven adult male orca in the New Zealand population that have bent, collapsed or collapsing dorsal fins (Visser 1998), which aids in making a positive identification from photographs. At the beginning of the study (1992), his fin was a Grade 3 (Fig. 2.21) and since it's collapse in 1996, has been reclassified as a Grade 5 (see Figure 4 a, b & c for illustrations of changes of the fin, in Visser 1998). He was first photographed in 1989 off Kaikoura.

Figure 2.21. NZ26 ('Topnotch'). This dorsal fin has a large notch out of the tip of the fin. In this picture it is a Grade 3 fin but was later reclassified as a Grade 5, when it began to collapse (see text and Visser (1998) for explanations).

NZ26 has been photographed around the New Zealand coastline 11 times during a seven year period (1989 - 1996). The farthest north that NZ26 has been photographed is the Bay of Islands, North Island (sightings # 9 & 11, Fig. 2.22) and the farthest south is off Kaikoura, South Island (sightings # 1, 2, 4 & 8, Fig. 2.22). The minimum distance between his northern and southernmost sightings is 3900 km. The distribution of sightings for NZ26 is similar to NZ29 (Fig. 2.24), (although NZ26 has not been sighted as often overall nor so often off the North Island). The distribution of sightings for NZ26 are skewed towards South Island sightings (N = 3 : S = 8), compared to NZ29, who's sightings are skewed towards the North Island (N = 5 : S = 2).

Figure 2.22. Location of Sightings of NZ26 ('Topnotch') (*n* = 11) from 1989 - 1996



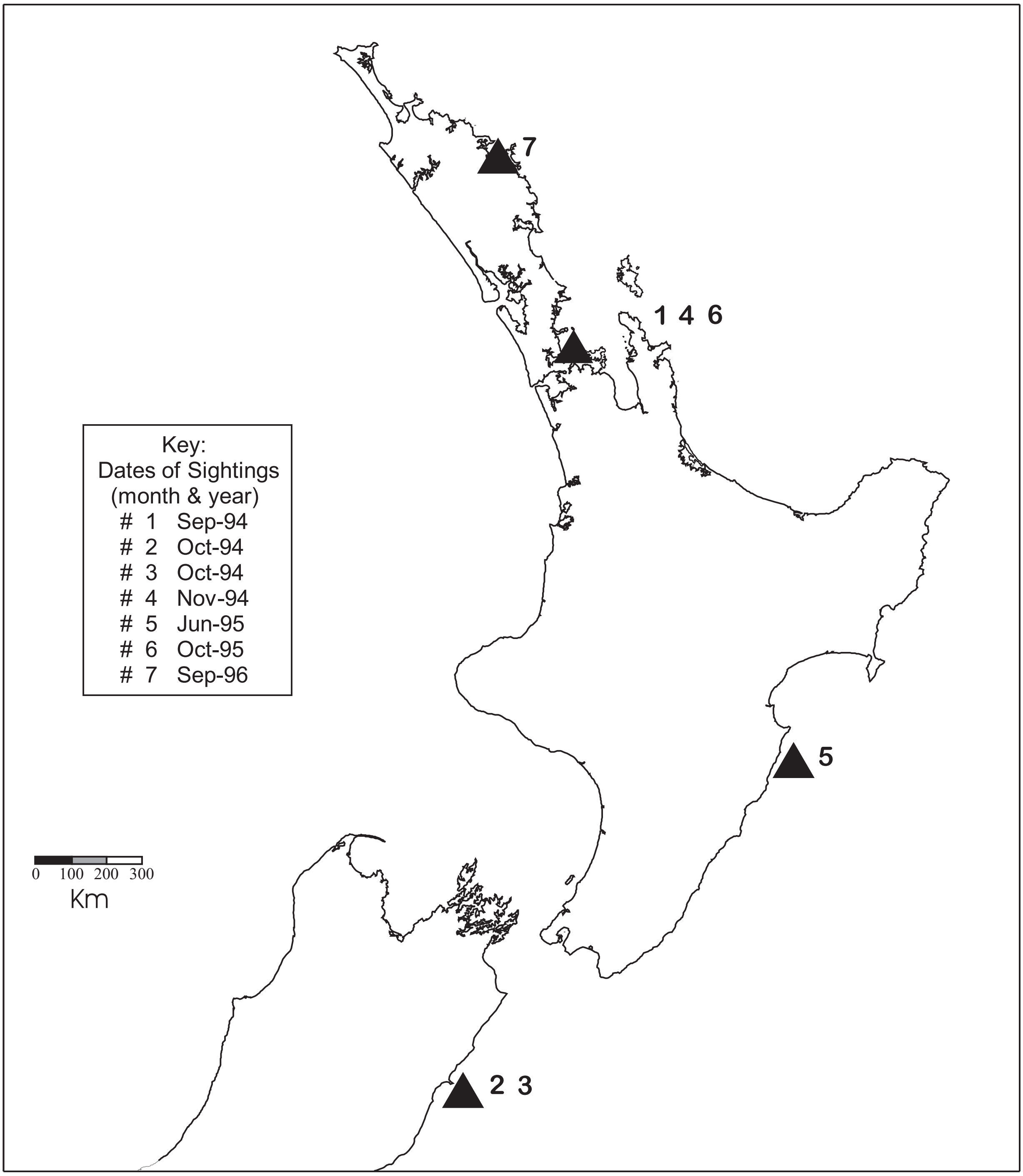
NZ29 ('TJ')

NZ29 is a subadult male. He is named after the initials of a research assistant. He has a Grade 2 fin, with a broad-based shape and a small 'dent' out of the tip of his fin (Fig. 2.23). He was first photographed in 1994 in Auckland Harbour.

Figure 2.23. NZ29 ('TJ'). This dorsal fin has a small 'dent' in the tip and is broad-based and triangular shaped (Grade 2).

NZ29 has been photographed around the New Zealand coastline seven times during a three year period (1994 - 1996). The farthest north that NZ29 has been photographed is the Bay of Islands, North Island (sighting # 7, Fig. 2.24) and the farthest south is Kaikoura, South Island (sightings # 2 & 3, Fig. 2.24). The minimum distance between his northern and southernmost sightings is 3900 km. Of note is the time frame and distance between sightings # 1 (Auckland Harbour) and # 2 (Kaikoura), i.e., 27 days, and no less than 3550 km, giving a minimum average distance of 131 km per day. Following this transit, the time frame between sightings # 3 (Kaikoura) and # 4 (Auckland Harbour) is 21 days, resulting in a minimum average of 169 km per day. The distribution of sightings, although only comprised of seven sightings, is similar to NZ26 (Fig. 2.22) (except for the skewed distribution of the sightings, see above).

Figure 2.24. Location of Sightings of NZ29 ('TJ') (*n* =7) from 1994 - 1996



Distribution Type (iii) South-Island-only

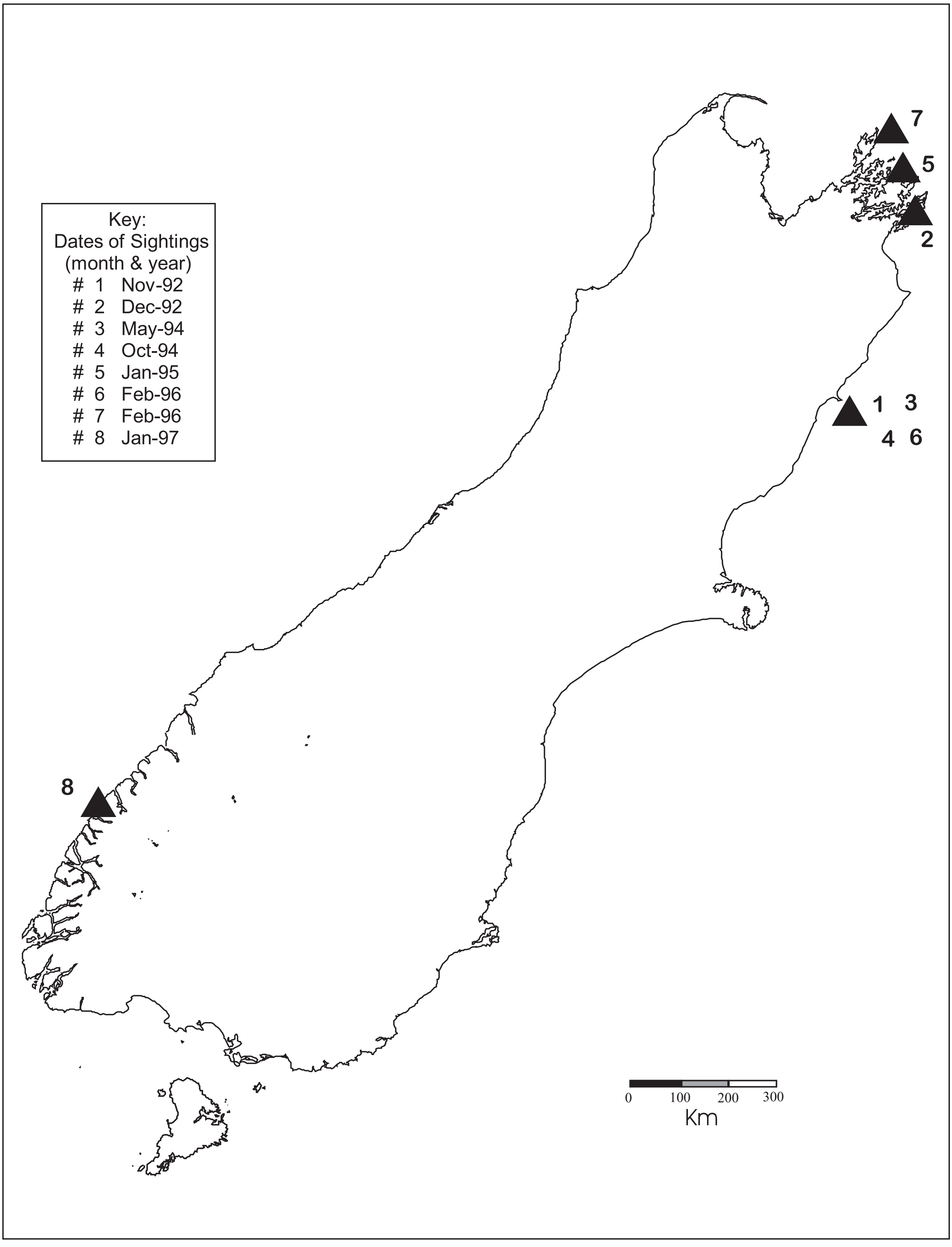
NZ23 ('Bill')

NZ23 is an adult male. He has two 'scallop' shaped indents in the trailing edge of his fin, suggesting the letter 'B' (Fig. 2.25), and has a Grade 4 fin. He was first photographed in 1992 off Kaikoura.

Figure 2.25. NZ23 ('Bill'). This dorsal fin has two scallop-shaped indents in the trailing edge, suggesting the letter 'B' (Grade 4).

NZ23 has been photographed around the New Zealand coastline eight times during a five year period (1992 - 1997). The farthest north that NZ23 has been photographed is the Marlborough Sounds, South Island (sightings # 2, 5 & 7, Fig. 2.26). The farthest south is Milford Sound, South Island (sightings # 8, Fig. 2.26), which is the southern most sighting location for any catalogued New Zealand orca. NZ23 has been photographed off Kaikoura, South Island on four occasions. The minimum distance between Milford Sound and Kaikoura is approximately 3000 km, regardless of which direction was taken (i.e, around the north of the island, or around the south). NZ23 has only been photo-identified off the South Island. However, he is one of only two orca (both adult males) to be positively identified on the west coast of the South Island (also see NZ15, Fig. 2.20). In addition he has also been photographed in the Marlborough Sounds and off Kaikoura, compared to NZ39 (see below), who has only been photographed off Kaikoura.

Figure 2.26. Location of Sightings of NZ23 ('Bill'), (n = 8) from 1985 - 1997



NZ39 ('Stealth')

NZ39 is an adult female. NZ39 gets her name from the stealth-like manner in which she hunts for dusky dolphins (*Lagenorhynchus obscurus*). She has a distinctive notch out of the trailing upper-section of her fin, and her fin is classified as a Grade 4 (Fig. 2.27). She was first photographed in 1988, off Kaikoura.

Figure 2.27. NZ39 ('Stealth'). This adult female has a distinctive shaped notch out of her fin (Grade 4).

NZ39 has been photographed nine times during an eight year period (1988 - 1996) (Fig. 2.28). All of the sightings of NZ39 have been made off the Kaikoura coast (Constantine *et al.* 1998, Visser 1999b). On all occasions when observed by the author, NZ39 either approached from the south or left the area heading south. From these observations, it is possible that the Kaikoura area is the northern extremity of the home range for this animal and the three other orca whom she travels with. NZ39 has only been photo-identified off the South Island. However, she is unlike NZ23 (see previous sighting profile) who has also been photographed in the Marlborough Sounds and the west coast of the South Island.

Figure 2.28. Location of Sightings of NZ39 ('Stealth') (n = 9) from 1988 - 1996

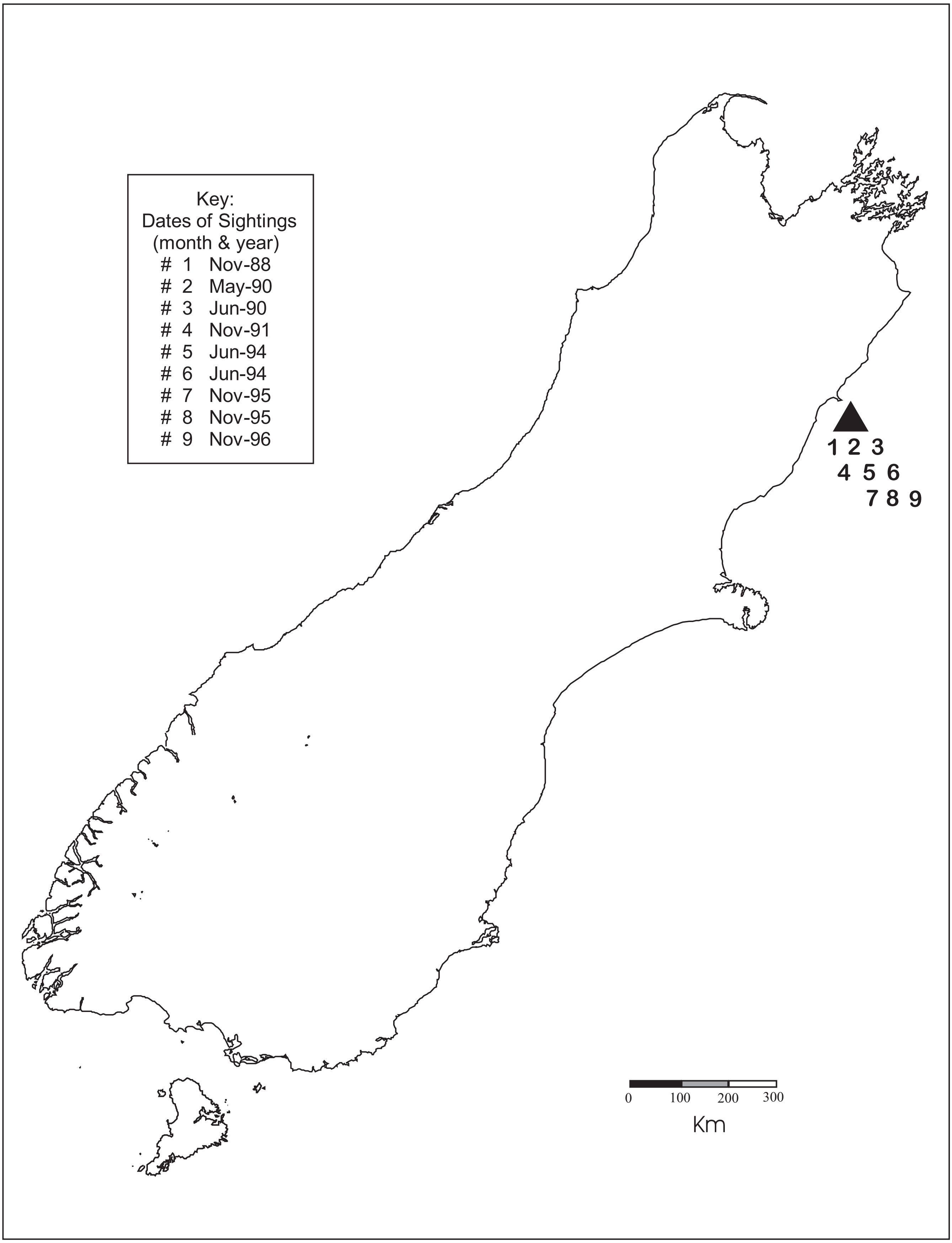


Photo Identification

General Distribution Trends Obtained from Photo Identification

As can be seen from the recorded distribution of the individuals outlined above, there appears to be patterns that are consistently different. Some individuals are seen solely off the North Island (North-Island-only), some solely off the South Island (South-Island-only), and others move between the two (North+South-Island). In addition, although not shown here, there are other individuals, such as the five animals recorded from the Three Kings Islands group, that have never been seen off either the North or South Island, although the island group's proximity (approximately 65 km from the tip of the North Island) would not preclude these orca travelling to the North Island. Still other individuals have been seen at locations of frequent orca sightings, but have only been recorded once (e.g., Visser 1999c).

Potential Sub-Populations

Taking the 50 individuals who have been seen more than five times, it is possible to suggest a number of potential sub-populations (Fig. 2.29). Seventeen animals have been seen only off the North Island. However there is a further subdivision, where some of these orca (n = 11) have been seen only off the East coast of the North Island (Fig. 2.29a). Yet others (n = 6) have been seen off both coasts (Fig. 2.29b). Although the sample size is much smaller (n = 6), a similar distribution has been seen off the South Island, with some animals (n = 5) only seen on the East coast (Fig. 2.29c), and one being seen off both coasts (Fig 2.29d).

Another group of individuals has been seen off both the North and South Islands. Again, these orca can be subdivided into sightings on each coast. One sub-group (n = 17) has been seen off the East coast of both the North and South Islands (Fig. 2.29e), and a smaller number (n = 9) have been seen off both coasts of the North Island and off the East coast of the South Island (Fig. 2.29f).

Figure 2.29. Distribution of orca (seen more than 5 times)

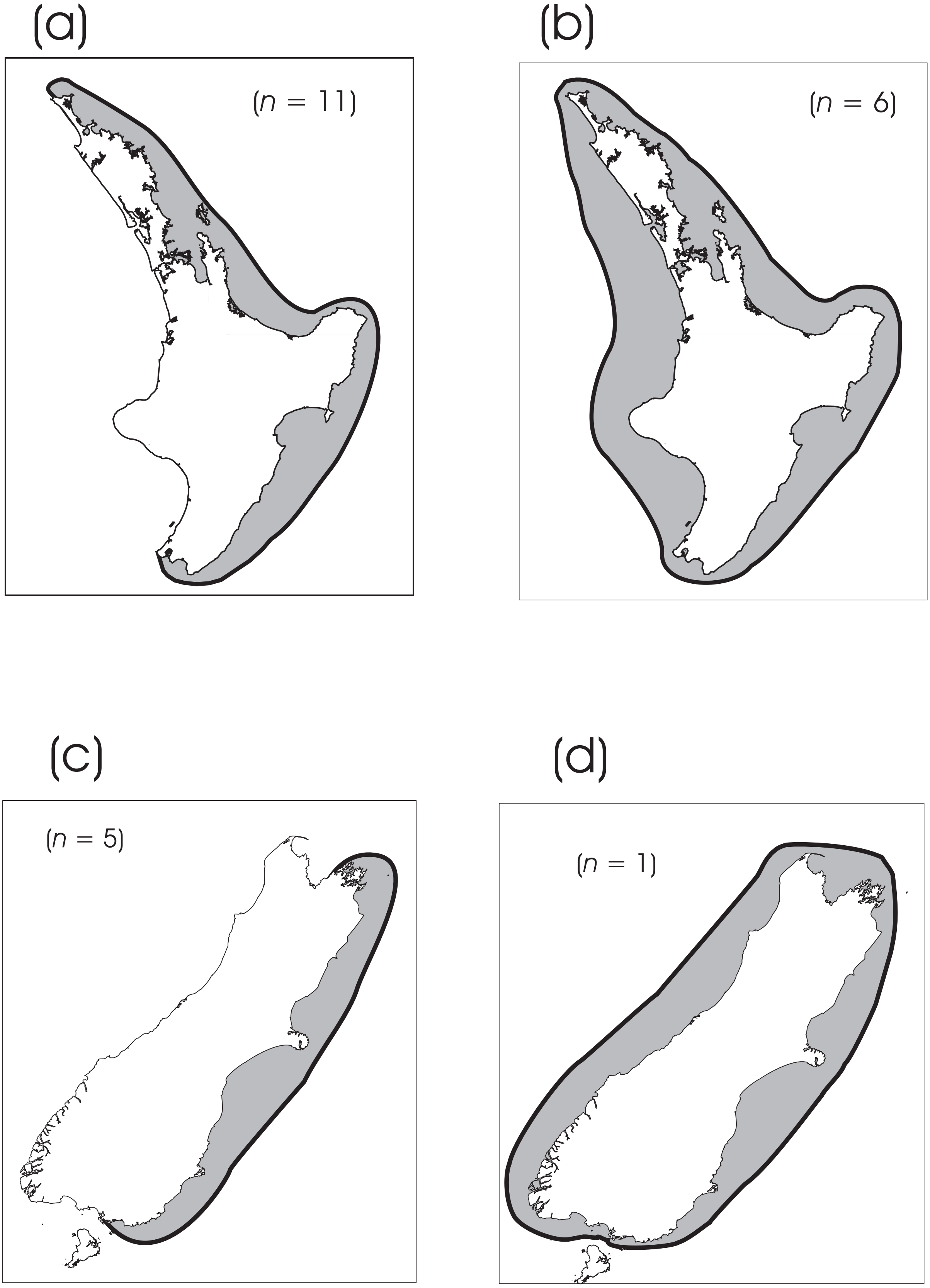
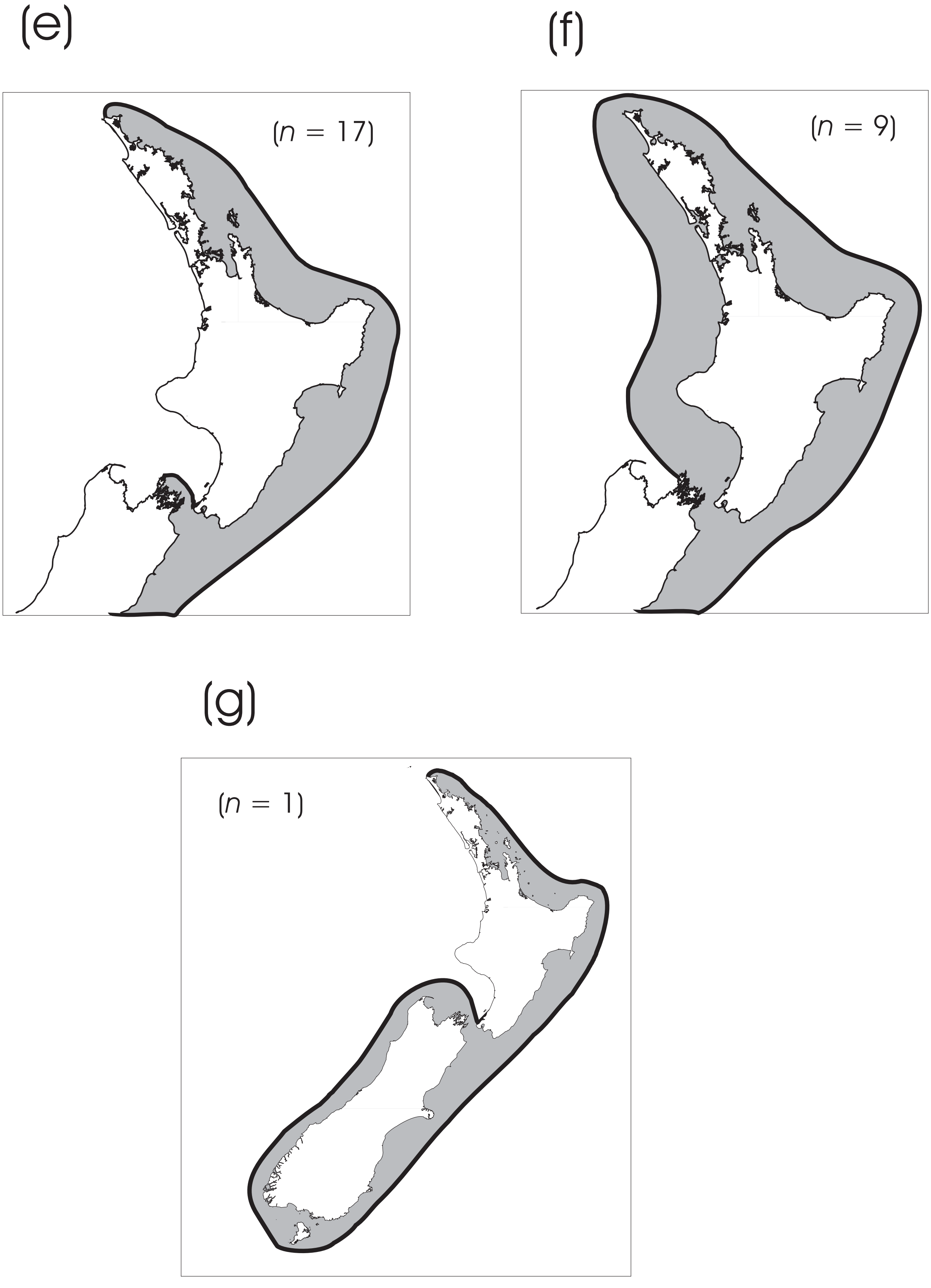


Figure 2.29. Distribution of orca (seen more than 5 times) con'td



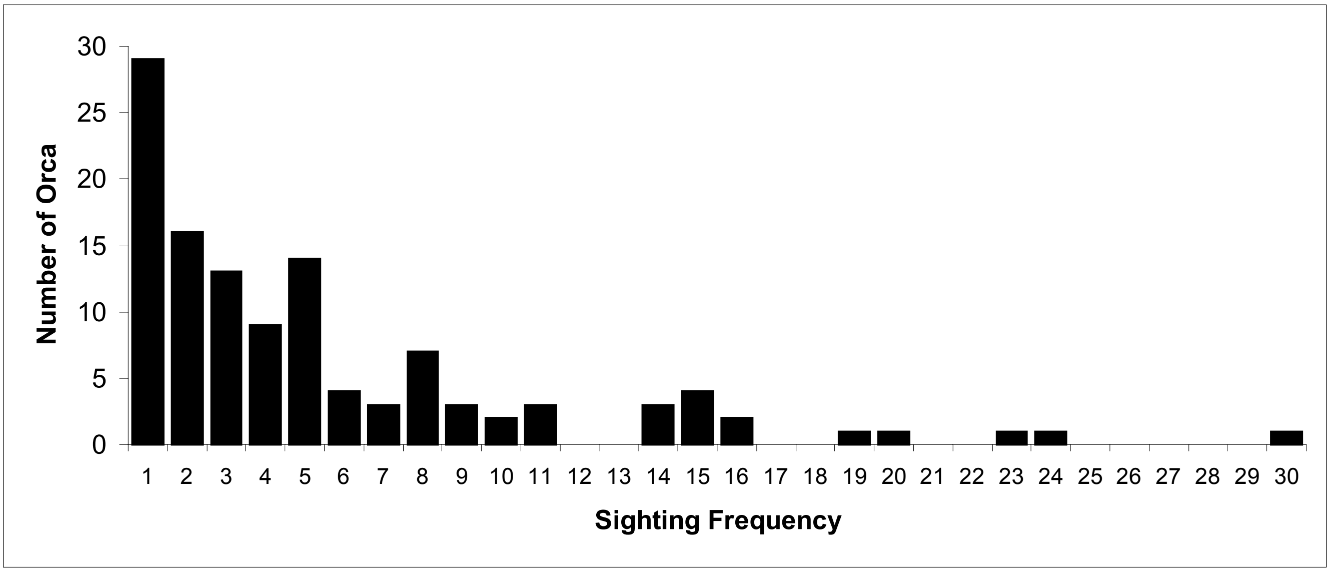
One animal (NZ15, Fig. 2.20) has been sighted off the east coast of the North Island, and off both coasts of the South Island (Fig. 2.29g). Within the North+South-Island group there also appears to be a skewing of distribution from North to South, i.e., some animals are seen more often in the North Island than in the South Island (e.g., NZ1, NZ6, NZ7), and other animals are seen more often in the South Island than in the North Island (e.g., NZ15, NZ26). Other orca seem to have a more evenly distributed sighting record between the Islands (e.g., NZ23). As the sample sizes were small, it is not possible to establish the significance of these differences. Although NZ1 (Fig. 2.14) has been recorded in four Regions, and NZ15 (Fig. 2.20) has been seen off both coasts of the South Island, and the east coast of the North Island, no orca have yet been recorded off both coasts of both islands.

Frequency of Resightings

During the period December 1992 - December 1997, 117 individual orca were photo-identified (see below). Of these, 75 % (n = 88) were seen on more than two occasions and 42 % (n = 50) were seen on more than five occasions. Twelve percent of orca (n = 14) were photo-identified on more than 10 occasions, and one orca on 30 occasions (Fig. 2.30). The mean number of sightings for the 117 photo-identified animals was 5.4, the mode was one sighting, and the median 9 – 10 sightings. Other individuals (n = 29) have been seen only once.

Although data collection 'effort' cannot be accounted for prior to this study, the photographs of identifiable orca collected pre 1992 are still of interest as they can contribute long-term information about individuals. Longevity and infrequent resightings are represented by at least one New Zealand orca - NZ1 (Fig. 2.14), who was first recorded (as an adult) in 1977, and was not seen again until 1989 (12 years). She was then photographed in 1990 and 1991, but not resighted again until 1994. After 1994, she was photographed each consecutive year up to and including 1997. Another female, NZ70, was first recorded in 1979, but was not seen again until 1990 (11 years).

Figure 2.30. Repeat sightings of individual orca.



Although some individuals were seen irregularly, others were seen regularly (up to 11 times per year). The mean number of years over which individuals were sighted was 3.8 years (mode 4, median 8). However, if the 29 animals that were only sighted once are not included, the mean number of years over which individuals were sighted rises to 4.7 years (mode = 4, median = 8.5). Given natural mortality rates (see below), some catalogued orca will be dead.

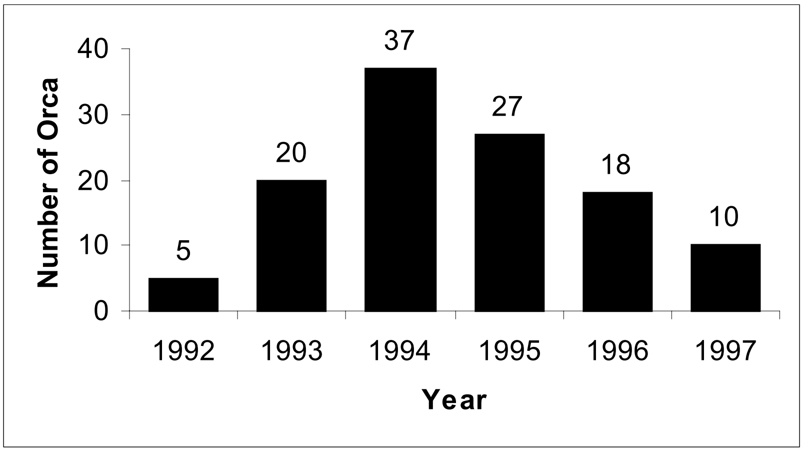
Population Estimates

Discovery Curve

Overall, discovery rates were slow, with the maximum number of orca catalogued in one year being 37 (Fig. 2.31). While there was a general trend towards a decline in the rate of new discoveries, the Discovery Curve (Fig. 2.32) contains a number of plateaus followed by steep increases. Many of these bursts of 'discovery' can be related to specific increases in effort as the following examples illustrate. Increase 1 (December 1992-February 1993); 10 orca 'discovered' relating to the initiation of the research project and collection of 'historic' records and photographs. Increase 2 (April-October 1994); 32 orca 'discovered' following the purchase of a boat for the research project, resulting in dedicated time out on the water with the animals. Increase 3 (July-December

95); 14 orca 'discovered' resulting from an increase in Researcher Effort, in both time out on the water and requests for information. Increase 4 (July-October 96); 10 orca 'discovered' following connection of a toll-free number which was extensively advertised to the public, resulting in an increase in the number of sighting reports, and consequently an increase in the number of encounters with orca. Increase 5 (April 97); during a trip to the outlying island group, the Three Kings, five orca were 'discovered' in one day.

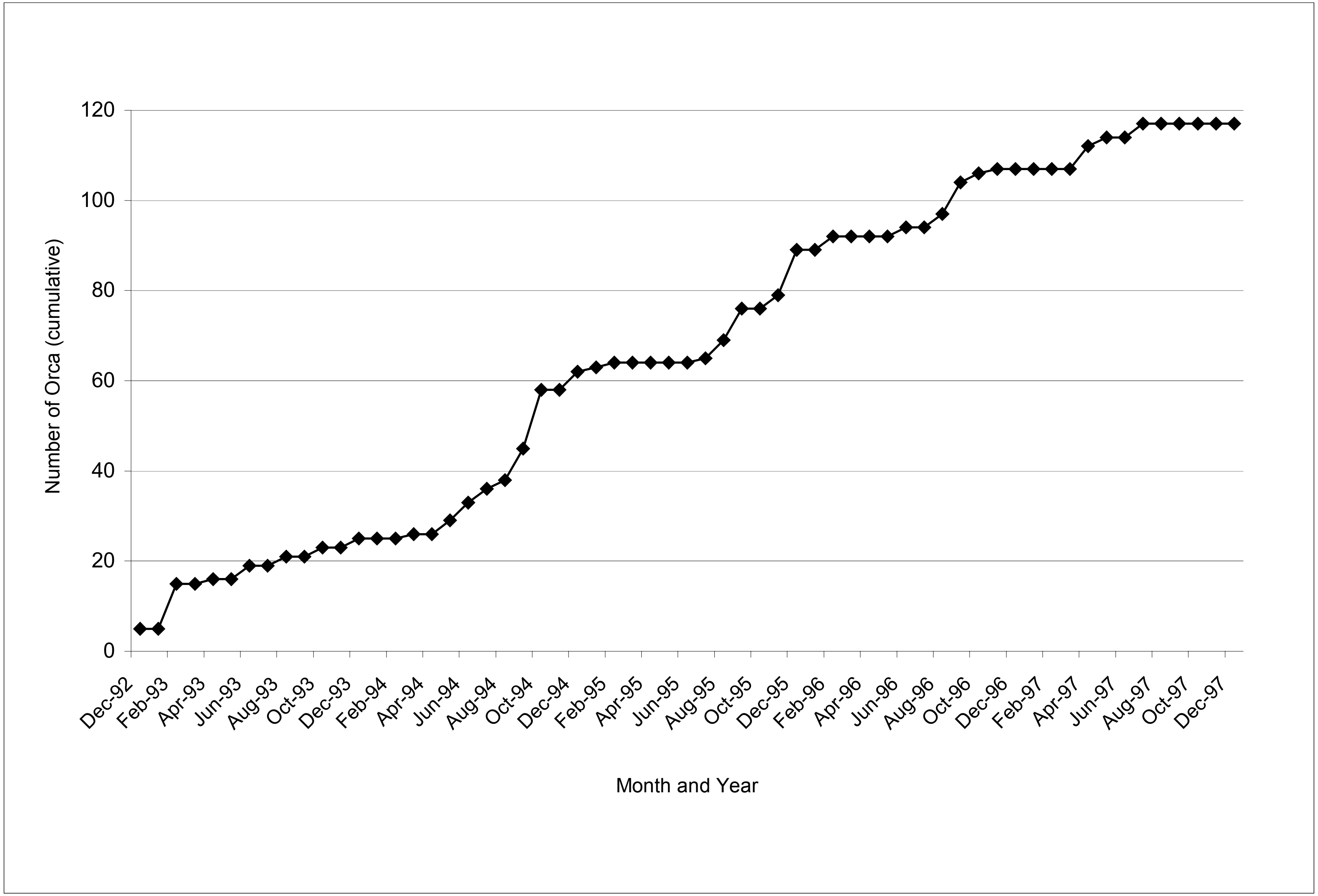
Figure 2.31. Number of orca catalogued each year (*n* = 117).



Total Enumeration (TE)

Using an average orca mortality estimate from Bigg (1990), Olesiuk *et al.* (1990), and Ford *et al.* (1994) of approximately 2% per year, it is possible to enumerate the population. Considering the longevity of individuals and infrequent resightings data (see above), the low frequency of resightings, or even failure to resight for up to 12 years, a lack of a resighting may not necessarily predict whether an animal was alive or dead in 1997. However, taking all individuals seen in 1997, plus all others last seen in previous years (devalued for mortality), a minimum estimate for most of the New Zealand orca population is derived (see Discussion). For December 1997, *n* = 115 orca.

Figure 2.32. Discovery Curve – Cumulative number of orca identified (1992 – 1997).



Jolly-Seber Population Model

For the Jolly-Seber population model, estimates at the beginning and end of the sample chains were unreliable due to small sample sizes. The more reliable sample chains occurred between (and including) the first six months of 1994 and the last six months of 1996. During this period, the sampling effort was high and consistent.

Some assumptions of this model needed to be checked, as allowed in POPAN-4.
Assumption (1): The survival rates of newly 'captured' (photographed) orca is the same as survival rates of previously 'captured' orca. The test showed that newly 'captured' orca, versus previously 'captured' orca, generally have the same probability of survival, with three sample times as exceptions. As this assumption was violated by three sample times, an alternative model to use would be the Modified Jolly-Seber model (Buckland 1980, Buckland 1990), which allows for heterogenous 'capture' probabilities. These could be expected from naturally marked whales (Buckland 1990). Fitting this model to the same data gives a population estimate in 1996 of 107 orca (± 24 SE), (with a 95% confidence interval based on the normal distribution [65, 149]).

Assumption (2): Every orca has the same probability of 'capture'. The test showed that the assumption of equal probability of 'capture' was violated at two of the sample times, leaving the sample of the last six months of 1996 as the most reliable, and not violated by either assumption. The size of the population in the last six months of 1996 was 119 ± 24 (*s.e.*) orca (95% confidence intervals based on a normal distribution [71, 167]).

Overall, these calculations show the orca in New Zealand have a population between 65 and 167 with the results from the TE and Jolly Seber calculations suggesting that the Total Enumeration in 1997 (i.e., 115 orca) is a reliable but conservative estimate.

Discussion

Regional Areas

The distribution of orca sightings by Regions closely reflects Researcher Effort in these same regions, and this has most likely contributed to the relatively high report rate for Region One (the author was based in this region for much of the study period). However, the possibility remains that the high number of sightings reported in Region One may also be due to a high usage of this area by orca, or may reflect a large sub-population of orca in this area.

Region Three had a small number of reports (n = 38), but the absence of any reports for August and September may reflect the increase in sightings in Region One during these months. The increase in sightings of orca in Region Four during the austral summer months may be linked to movements of dusky dolphins (*Lagenorhynchus obscurus*) which move closer into shore around Kaikoura at this time (Cipriano 1985). Some New Zealand orca are known to prey on dusky dolphins (Visser 1999b). They may be following their food source, as has been reported for other orca populations which show seasonal distributions linked to prey availability (e.g., Condy *et al.* 1978, Heimlich-Boran 1986, Heimlich-Boran 1987, Jonsgård and Lyshoel 1970, Norris and Prescott 1961, Similä *et al.* 1996). Region Five appears similar to Region Four, and additional sightings for this area may help to clarify if it does indeed have a similar sighting pattern. Although no trends were conspicuous in Region Six the apparent increase of sightings in austral summer months may not be reliable as there were so few reports overall.

The low number of sightings from the Sub-Antarctic Islands was unexpected, given the high numbers of orca sighted at other Sub-Antarctic Islands such as the Crozet Archipelago, Marion Island and Macquarie Island (Condy *et al.* 1978, Copson 1994, Guinet and Bouvier 1995). More than 40 days have been spent by the author in the various New Zealand Sub-Antarctic Island groups, and no orca sightings were made. Although the New Zealand Sub-Antarctic Islands have low levels of human occupation, so too do the other islands listed above. Higher reporting rates could be expected for the Auckland and Campbell Islands during 1941-1945 as full time personnel were kept on "Coast-Watch" for enemy shipping. These personnel were instructed (by the RNZ Navy Office) in addition to service routine, to record general observations on natural phenomena. These were published as the 'Cape Expedition' series (the war-time code name for the parties in the field between 1941-1945). These concentrated efforts only resulted in one orca sighting being published from either archipelago (Sorensen 1950). In comparison, the high number of orca reports from the Chatham Islands may be linked to the strong fishing community.

Photo Identification

<u>Using Photo-Id Methods</u>

Validity and reliability of photo-id work is based on standard 'mark and recapture' techniques, which have inherent biases. Although photo-id is relatively non-invasive, there is a potential bias to underestimate unmarked animals (therefore resulting in an underestimation of the population), or to overestimate individuals with highly distinctive marks, regardless of the quality of the photograph or proximity of the animal. To prevent these types of bias by the researcher, orca were photographed randomly and strict criteria followed for which photos were included in the analysis. When sourcing images from the public, it is possible that certain types of animals may be photographed more often (Buckland 1990). However, in this study all grades of fins (from the researcher and the public) were equally photographed.

Buckland (1990) suggested that cetacean photo-identification projects should continue for at least ten years with an intensive program maintained throughout this period. Hammond *et al.* (1990a) noted that the inconsistency of the results for their photo-id study of blue whales (*Balaenoptera musculus*) could be explained through a combination of the sampling effort within the study area, and the distribution of the animals themselves. For this study, sampling was not consistent over the whole of New Zealand, but concentrated mainly on the north of the North Island and the upper half of the South Island (Regions One and Four). By concentrating more effort in the other Regions, it is likely that more orca would have been identified, or known individuals resighted more often and in other Regions.

Home Ranges

No individual orca have been sighted in all six Regions, although one orca (NZ1) was recorded in four Regions (Fig. 2.20). It could be expected that closely associating animals may later prove to have a wider home range than recognised now, based on sighting information for their frequent companions. Over time, additional information about the home ranges of individuals may become available. For instance, verbal reports of NZ15 (Corkscrew) have suggested that he frequents the west coast of the North Island, however, to date, no photographic evidence has been gathered. The number of orca sighted on both coasts of either island (North Island, n = 15; South Island, n = 2) was low when compared to the number of orca seen on the east coast of both islands (n = 36). These sightings may reflect the true home ranges or may be biased due to increased monitoring of eastern areas (see Researcher Effort above).

Studies of other small cetaceans in New Zealand waters have demonstrated some individuals, as well as certain populations, to be highly localised. Dawson and Slooten (1993) recorded Hector's dolphins moving a maximum of 34 NMi and Williams *et al.* (1993) found a population of bottlenose dolphins to be resident in a deep fiord system (of about 22 NMi in length) in the South Island. The maximum distances recorded between northernmost and southernmost sightings for individuals in this study (e.g., NZ1 & NZ15, minimum distance 4200 km; NZ6, NZ7 & NZ26 minimum distance 3900 km) show some animals move great distances, even within their known home ranges. That others (e.g., NZ39 Fig. 2.28) are consistently found at the same location, or in small home ranges (e.g., NZ63 Fig. 2.12) suggests that some orca may move small distances.

Spatial and temporal distribution of sightings can also be used to calculate the distances individuals may travel within their home ranges (e.g., one individual (NZ25) travelled at least 15600 km in six years, Visser 1999a).

Possible Sub-populations

The three possible sub-populations identified (i.e., North-Island-only, North+South-Island, and South-Island-only) are unlikely to be artefacts of sample size, as:

(a) the number of regions individuals were photographed in is not related to the number of sightings of that individual, e.g., NZ6, was photographed 30 times in three different regions *cf* NZ15, photographed 10 times in four different regions;

(b) the distribution of sightings shows a decline in some areas in certain months, which is associated with increases in other areas in the same months (e.g., compare Fig. 2.7a and 2.7c), which suggests seasonal movements; and

(c) the presence of infrequent sightings of orca that are passing through the area is reinforced by sightings of animals that have pigmentation patterns previously only described from Antarctica (Visser 1999c).

Frequency of Resightings

Fifty orca have been sighted five times or more, with one having been photographed 30 times and another having been seen around the coast of New Zealand for 20 years. Eighty-eight animals have been sighted for two or more years, and this, along with the median number of years over which individuals have been sighted (3.8 years) suggests that at least 75% of the known orca population may be autochthonic to New Zealand waters. However, the paucity of data for some areas is relevant to the Researcher Effort, which suggests that an increase in effort would bring an increase in sightings and size of some home ranges. Certain areas could be targeted, such as Region Six (the west coast of the South Island), which might increase the knowledge of known animals, and Region One (Northland etc.), for ease of continued monitoring.

As 29 individuals have only been seen once, these animals may represent part of the population who have died, or are difficult to photograph. Or, these could represent animals passing through the area, which may or may not legitimately be part of the New Zealand population. For example, one group of individuals, seen once off the Bay of Islands, had markings usually attributed to Antarctic orca (see Visser (1999c) for full details).

Population Estimates

The size of the New Zealand orca population is estimated to be small whichever estimate is used (117 individuals photo-identified up to, and including 1997, 115 orca estimated as the Total Enumeration as of 1997, and 65-167 individuals in the last six months of 1996 from the Jolly-Seber calculations). The estimates suggest that from a conservation perspective, the New Zealand orca population is small and requires attention.

Under Canadian Marine Mammal Regulations, one population of 'resident' orca (n = 200), (Ford *et al.* 1994) has recently been designated as threatened (Baird 1999), and another population, that of the 'transient' orca (n = 79), (Black *et al.* 1997, Dahlheim *et al.* 1997, Ford and Ellis 1999, Matkin *et al.* 1999), have been designated as vulnerable (Baird 1999). Baird (1999), who prepared the report which led to the populations' status designations, commented that without a threatened classification for a population of orca, it is unlikely that anything will be done regarding mitigation of potential impacts to the population (for examples of potential impacts to New Zealand cetaceans see Slooten and Dawson (1995), and Chapter Six).

<u>Discovery Curve</u>

Although the general trend of the curve implies that the majority of the animals in the population have been identified, the lack of a final asymptote for the Discovery Curve is suggestive that greater effort would have produced more individuals. Increased Researcher Effort in Regions Five and Six may have provided some increases in the number of identified animals, although previous increases in activity in these Regions failed to provide the type of dramatic increases that followed increased activity in the other Regions. Orca not yet included in the photo-identification catalogue may be animals already found in the area but not yet photographed, or new immigrants (through true immigration and births). Also, if births and/or immigration occur in the New Zealand population, the Discovery Curve will continue to show a small increase.

<u>Total Enumeration (TE)</u>

Although the TE avoids the biases that inevitably result from the violation of the assumptions of population models, one component of calculating the Total Enumeration is allowing for mortality. This is unknown for New Zealand orca, but it is assumed the rate used from the PNW animals of 2% (Olesiuk, *et al.* 1990) is a realistic approximation for this population.

<u>Jolly Seber Population Model</u>

If there had been a higher percentage of new animals during each sampling period (i.e., per six months, as used in the POPAN-4 analysis) it could be assumed that the population was completely open, containing more animals that were passing through the area (Weigle 1990). Although 21% of animals have been sighted only once, and some orca may truly be transiting (Visser 1999c), it is possible that longer term studies (as suggested by Buckland 1990) will give a higher rate of resightings, as has been found for other areas (Bigg *et al.* 1990, Matkin *et al.* 1994).

The test for Assumption (1) showed that newly ‘captured’ orca generally have the same probability of survival as previously ‘captured’ orca. Nevertheless, if the newly ‘captured’ orca are calves less than one year old, for whom mortality rates are estimated to be 43 % (Olesiuk *et al.* 1990) (*cf* adults, where mortality rates are approximately 2%), there may be a strong bias in survival rates. However, due to the difficulties of identifying calves (Visser and Mäkeläinen 2000), only 11 are included in the total record and hence this bias is liable to be small.

Population Estimates Overall

The Jolly-Seber model may not be robust when assumptions are violated. For example, in the Hammond *et al.* (1990a) photo-id study of blue whale populations in the Gulf of St Lawrence, the highest estimate acquired (using a Jolly-Seber method) was smaller than the total number of photo-identified whales (estimated 193, actual photo-identified 202). This result was thought to be influenced by inconsistent data (Hammond *et al.* 1990a). In this study, because of violations and the nature of the data, the two population estimates calculated (i.e., using the Jolly-Seber and Total Enumeration models) are likely to underestimate the true population size (Hammond *et al.* 1990b). The TE in December 1997 was 115, which is only four less that the unmodified Jolly-Seber model estimates (n = 119), and is ten more than the modified version (n = 105). Therefore, the Jolly-Seber population estimates provide no greater information than the more simple TE, as has been shown in other studies (e.g., Hammond *et al.* 1990a, Moller and Craig 1987). Although Researcher Effort was adequate for Regions One, Two, Three and Four, it is likely, had more effort been applied to Regions Three and Six, the population estimates would be higher. Therefore, allowing for this, it would be reasonable to extrapolate these results and estimate the total New Zealand orca population to be in the low hundreds.

Conclusions

Although the New Zealand population of orca is most likely part of a total world meta-population - given that only one migrant per generation is considered enough to connect a population to others (Mills and Allendorf 1996), the methods used to estimate population size all suggest that the local population is extremely small. It is certainly well below the 500 suggested by Soulé (1987) as a viable population. Because it appears to be further divided into sub-populations, the risk of local extinction may be extremely high. Caughley (1994) pointed out that small populations may face threat from extinction due to the intrinsic nature of the size of the population. Following Buckland's (1990) suggestion of intense monitoring for at least ten years, for photo-id studies of cetaceans, continued long-term monitoring of at least Region One, and increased Researcher Effort in Regions Four and Six, should result in more resightings and may produce new individuals. However, one of the major issues still to be determined about the New Zealand population of orca is how physically and reproductively isolated the various apparent sub-populations are. Aspects of this are investigated further in Chapter 3.

Even if the New Zealand population is not subdivided, its small size warrants a declared conservation management status. Only New Zealand authorities are able to conserve these animals. Given the effort that is put into other species found in New Zealand which are known to be common in other parts of the world (e.g., kotuku or white heron, *Egretta alba*), failure to act for orca would be inconsistent.

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CHAPTER THREE

Population structure and associations of New Zealand orca (*Orcinus orca*)

ABSTRACT

The total New Zealand orca population is small and appears to be made up of at least three sub-populations based on geographic distribution. Sex ratios for the total population and for possible sub-populations do not differ from 1:1. Young are present in all populations, although ratios appear to differ. Association Indices are compared within and between the proposed North-Island-only, South-Island-only and North+South-Island sub-populations as a test of possible sub-divisions. As expected there were no associations between individuals of the North-Island-only and South-Island-only sub-populations. The mean associations within the North-Island-only and South-Island-only sub-populations are significantly greater than between these two sub-populations and the North+South-Island sub-population. The Association Indices were low within the North+South-Island sub-population, and low between this sub-population and the other two sub-populations, suggesting there may be a further sub-division within the North+South-Island sub-population. Comparisons were made between animals that shared food and animals that did not, to determine if frequency of association is reflected in other affiliative behaviour. Associations were much higher between animals that shared food. Preliminary mtDNA analysis supports the hypothesis that some New Zealand orca do not mix. Whether the proposed three sub-divisions within the New Zealand orca population are reproductively isolated and hence require separate management, and whether there is further sub-division within the proposed North+South-Island sub-population, requires further study, including genetic analysis.

Introduction

Generally, the management of populations under threat of extinction is evaluated from two perspectives; the small population paradigm (which deals with the *effect* of smallness) and the declining population paradigm (which deals with the *cause* of smallness) (Caughley 1994). For many marine species, consideration of population trends is recent and hence there is minimal information to argue for a decline, or for the severity of this (Towns and Ballantine 1993). In order to determine the likely importance of factors considered under the small population paradigm, it is beneficial to understand the demographic structure of the population, including sub-populations. New Zealand orca (*Orcinus orca*) are apex predators, appear to have a relatively small total population size, and the data suggests possible structuring of this population into a number of sub-populations (Chapter Two).

In the waters of the Pacific North West seaboard (British Columbia, Washington and Alaska, hereafter referred to as PNW), studies of orca have been ongoing since 1970. The studies based there have provided the most detailed information on orca anywhere in the world and include information on genealogy as well as population structure (e.g., Ford and Ellis 1999, Ford *et al.* 1994, Matkin *et al.* 1999, Matkin *et al.* 1998, Olesiuk *et al.* 1990). In other parts of the world, several photo-id studies have been running long-term, such as in Norway where studies began in 1983, and where orca are seasonally abundant through October to January (Similä *et al.* 1996). In the Southern Hemisphere, there are few orca research projects; e.g., a short term study in Brazil (Secchi and Vaske 1998), an intermittent seasonal study along the coast of Peninsula Valdés, Argentina (Lopez and Lopez 1985), and a mostly land-based study conducted 1987 – 1990 at the Crozet Islands (Southern Indian Ocean) (Guinet 1991).

Worldwide, orca have been shown to exist in small populations that may or may not interbreed (Baird 2000). Each of the well studied populations in the PNW appear to have a different basic structure (Baird 1999, Ford and Ellis 1999, Ford *et al.* 1994, Matkin *et al.* 1999), however, all the populations are small (< 500) and hence are vulnerable to stochastic extinction (Barrett-Lennard 1999, Caughley 1994). For any orca population, the structure, and the inherent social organisation of the animals within it, has important implications in terms of the frequency of gene exchange between the sub-populations that potentially form a larger meta-population. For instance, if gene exchanges between groups is rare, kin mating within groups may enhance inbreeding depression through gene loss. This in turn would, according to the small population paradigm, increase the potential for extinction (Caughley 1994). The mechanisms of inbreeding depression are poorly understood (Caughley 1994) but a population which has gone through a bout of inbreeding may come out of it with enhanced fitness, because deleterious recessives may be exposed allowing them to be purged from the gene pool (Caughley 1994). This is precisely the method used by animal breeders to remove deleterious alleles (Alderson *et al.* 1994). Alternatively, in some populations where mating is often between kin, such as New Zealand birds (Craig 1991), inbreeding levels appear high, precluding the build up of deleterious recessives. Some orca are known to closely associate with kin (Ford *et al.* 1994), but whether kin mate with kin is poorly understood.

Recent analysis of skin and blubber samples taken from orca from the PNW populations (Barrett-Lennard 1999) has confirmed early studies by Ford and Fisher (1982) who speculated on the isolation of orca populations based on acoustical behaviour, and that pod-specific repertoires probably acted as behavioural indicators of pod affiliation (Ford 1991). The early studies in the PNW suggested two distinct forms of the species ('resident' and 'transient') with a third form ('offshore') identified but not yet studied in any depth. The two well known forms differ in many respects, including diet and acoustics, and appear to be socially and genetically isolated, even though they inhabit the same area (Bigg 1982, Bigg *et al.* 1987, Ford and Ellis 1999, Ford *et al.* 1998, Hoelzel and Dover 1991).

Association Indices are a measure used by researchers to support the existence of potential group structures within a population. They have been used by cetologists for a variety of species, e.g., humpback whales (*Megaptera novaeangliae*) (Clapham 1993), bottlenose dolphins (*Tursiops truncatus*) (Ballance 1990, Bräger *et al.* 1994, Conner *et al.* 1992, Schneider 1999, Smolker *et al.* 1992), Hector's dolphin (*Cephalorhynchus hectori*) (Bejder and Dawson 1997, Slooten 1990), spinner dolphins (*Stenella longirostris*) (Östman 1994) and orca (Heimlich-Boran 1986, Heimlich-Boran 1988). Results from PNW orca show that some individuals are regularly sighted together, whereas others are never sighted together, and may avoid each other (Baird 1994, Ford and Ellis 1999, Ford *et al.* 1994).

In social animals kin are often seen together (Fletcher and Mitchener 1995), e.g., chimpanzees (Goodall 1991), gorillas (Fossey 1974, Fossey 1983), baboons (Cheney 1978), hyenas (Holekamp and Smale 1990), swamp hens (Craig and Jamieson 1988), elephants (Moss 1988) and orca (Ford *et al.* 1994, Heimlich-Boran 1986). These associates often participate in joint activities, including playing (Cheney 1978, Fossey 1983, Goodall 1991), assisting in rearing young (Craig and Jamieson 1988), alloparenting and 'baby-sitting' (Bisther and Vongraven 1993, Bisther and Vongraven 1995, Vongraven 1993, T. Similä pers. comm., Visser, unpubl. data,), care-giving behaviour (Ford *et al.* 1994), carrying deceased (Conner and Smolker 1990, Schneider 1999) and food sharing. Food sharing has been reported for various taxa, e.g., hyenas (Holekamp and Smale 1990), lions (Schaller 1972), chimpanzees (Goodall 1991), gorillas (Fossey 1974, Fossey 1983), swamp hens (Craig and Jamieson 1988) and for cetaceans (whales, dolphins and porpoises), e.g., delphinids (Fertl *et al.* 1995) and orca (Baird 1994, Baird and Dill 1995).

New Zealand orca appear to have a small population size and the data suggests that certain animals use different parts of the coast and hence may form distinct sub-populations (Chapter Two). Some individuals are regularly sighted together, display alloparenting and baby-sitting behaviour and have been observed sharing food. This chapter seeks to elucidate population structure (age and sex ratios) and, through the use of associations indices and food sharing between known individuals, evaluate the likelihood of these population sub-structures.

Methods

Photo Identification

All orca in a population can be uniquely identified with high-quality photographs (Baird 2000, Bigg 1982, also see Chapter 2 this volume). Due to this uniqueness, focal sampling (Altmann 1974, Baird 2000, Mann 1999) is possible, allowing behavioural observations to include aspects such as food sharing and associations.

Home Ranges

One hundred and seventeen individual orca have been photo-identified (Visser 1999). Fifty of these animals were seen on more than five occasions. They were separated into three possible sub-populations, based on their known home ranges, as demonstrated in Chapter Two.

Age/ Sex Classification

Photo-identified orca were grouped by age and sex following Bigg (1982). Age was estimated by comparing relative size of the animal and size of the dorsal fin (Bigg *et al.* 1990). These groupings were; 'Adult Male', categorised by having distinctively large dorsal fins; 'SAM' (Sub-Adult Male), the fin had begun to grow or 'sprout' but was not yet as big as an adult male's fin; 'Adult Female', seen to be constantly accompanied by a calf, or to suckle a calf, or the genital area had been viewed and sex determined; 'Juvenile', between 0.5 to 0.75 the size of an adult female, but still larger than calves; 'Calf', less than 0.5 the size of an adult female and when very young (less than a few months), 'yellow' in colour; and 'Unidentified', orca which were yet to be assigned to an age/sex class (see Bigg (1982) for full details). Although there may be some overlap with adult females and young males, as males which have not begun to 'sprout' have similar sized fins to females, generally most orca could be assigned an accurate sex class, as studying an individual for several years usually determined if the animal was a subadult male or female.

Group Size

Population estimates rely on the validity of the data provided, therefore it is important to know if there are any biases so that corrective measures can be taken. To judge if the photographic 'capture' of individuals was a genuine representation of group size, the number of animals in each group was estimated and then compared to the number of animals actually photographed. Photographs of orca groups were taken by the author during 55 encounters. The estimated group size and the number of animals photographed were closely related (82% of estimated group sizes were within two individuals of the photographed group sizes). Therefore the estimated group size was used throughout the duration of the study.

Association Indices

The assumption is made that orca seen and photographed during the same encounter in the same group and area are in association with each other. However, as cetaceans can, in theory, communicate over great distances, it is feasible that even if all animals seen by the researcher were photographed, there were other animals travelling within the 'acoustical group' that were not recorded. However, these affiliations (if they exist at all) are impossible to determine in the field. Consequently, the analysis used here only involved individuals that were photographed, and did not include animals that were seen and not photographed, or others that might have, for instance, been reported by another boat over the radio. An arbitrary measure (taking into consideration the issues above) was set, whereby orca that were within 500 m of each other were considered to be associated.

The possible sub-populations were used to test whether basic demographics of sex and age ratios differed and whether there were differences in association. These associations were assessed to produce an 'Association Index'. The Association Index chosen followed Cairns and Schwager (1987) who suggested a formula they refer to as the Half-Weight Index, which would be the least biased for studies where animals are more likely to be recorded separately than when together. This bias is likely to occur in photographic studies (which are typically conducted for cetaceans), where the number of mutual sightings is likely to be underestimated. There are two reasons why this might happen: firstly, before two individuals can be scored as sighted together, both must be seen and photographed; secondly, when two individuals are separate this can be recorded if either of the two individuals is photographed, whereas only one individual can provide association data when they are together (Cairns and Schwager 1987).

Therefore, the Half-Weight Index is commonly used in studies of cetacean associations, e.g., spinner dolphins (*Stenella longirostris*) (Östman 1994), bottlenose dolphins (*Tursiops truncatus*) (Bräger *et al.* 1994, Conner *et al.* 1992, Schneider 1999), Hector's dolphin (*Cephalorhynchus hectori*) (Bejder and Dawson 1997, Slooten 1990, Slooten *et al.* 1993) and orca (Heimlich-Boran 1986).

The Half-Weight Index formula is:

$$\frac{x}{x + 1/2\,(y\mathrm{A} + y\mathrm{B})}$$

where x is the number of sightings that included both animal A and animal B in the same group,
yA is the number of sightings that included animal A, but not animal B, and,
yB is the number of sightings that included animal B, but not animal A.

The higher the Association Index (i.e., the closer the number is to 1), the more time the animals spend together. A value of zero would indicate that two animals were never seen together. When using an Association Index that is limited to analysis of dyads, by default, the test of association is between two animals. However, in a group of, for instance, three orca, each animal present is considered to have two associations, but each would be calculated independently. Consequently any multiple associations (no matter how many orca were present in a group) were all calculated separately, as if they were dyads. In addition, animals were recorded as being together once for any particular sighting event. However, some of these animals were in close association for periods of up to 14 hours, whereas others were observed closely associated for time periods as short as two hours. Hence the Association Index only measures one dimension of social association.

Food Sharing

Behavioural observations were made following the *ad libitum* protocol described by Altmann (1974) and Mann (1999). In addition, every three minutes (using a timer) instantaneous sampling was conducted (Mann 1999). Food sharing was determined when one orca was seen with prey in its mouth, and either at the surface or underwater, exchanged the prey, or part of it, with another orca. As it is not possible to distinguish between provisioning and food sharing based on size alone (e.g., adult orca have been observed taking food to other adult orca), no distinction is made between food sharing or provisioning and hereafter both are termed food sharing.

Whilst holding prey in its mouth, orca were often seen to ‘hunch’ over a prey item, or ‘shake’, where their whole body or dorsal fin was seen to rock violently from side to side. Both of these behaviours were used as an indication that a prey item was held. Termination of food handling was noted when the orca no longer carried any part of the prey, nor conducted the above behaviours.

When food sharing occurred at the surface, the animals could be seen lying either side by side, or with an approximate angle of 30 degrees between their bodies, or lying head to head. Often during these exchanges, one or both of the orca were seen to 'shake' as described above. Some food exchanges occurred just below the surface and no doubt others occurred at depth and were not observed.

Circle Plot

Of the 50 orca seen more than five times, Association Indices between potential dyads (n = 1225) were, for a vast majority, below 0.2 (n = 1128) with many of the individuals having no association between each other at all (i.e., an Association Index of 0, n = 857) (see Appendix 1 for details). However, 41 of the 50 orca seen more than five times had an Association Index of 0.33 or above with at least one other orca. These Association Indices were plotted in a graphic 'circle-plot', whereby the codes for the orca (e.g., NZ1, NZ50) were placed in a circle and lines of different thickness drawn to represent the Association Index value, in a similar method to that used by Östman (1994) when describing the social organisation of spinner dolphins off Hawaii.

Results

Age/Sex Classification

Of the 117 orca photo-identified, 47 were presumed to be females, 35 were confirmed as adult males, 13 were confirmed as SAM's, two were juveniles, 11 were calves and the age or sex class could not be determined for a further nine orca. Adding the adult males and SAM's together gives a sex ratio of 47 females to 50 males. This sex ratio is not significantly different from a 1:1 sex ratio ($X^2 = 0.67$, $df = 1$, $p < 0.5$).

Using the possible sub-population designations, a further break down of the age/sex structure of the population is possible (Table 3.1). For the groups with an adequate sample size (i.e., North-Island-only and North+South-Island), sex ratios do not significantly differ from a 1:1 ratio ($X^2 = 1.67$, $df = 1$, $p > 0.2$ and $X^2 = 1.0$, $df = 1$, $p > 0.2$ respectively), even though there does appear to be more males. Both populations have young and hence are breeding, although the ratio of young appears higher in the North-Island-only group, than the North+South-Island group (38% **:** 15% respectively). Calves and juveniles, although present, may not always have been photo-identified, so may not be included in this age/sex breakdown and other calculations. However, 83% (*n* = 46) of encountered groups contained at least one calf and/or juvenile. Calves and juveniles were recorded in all months of the year, regardless of where the group was encountered.

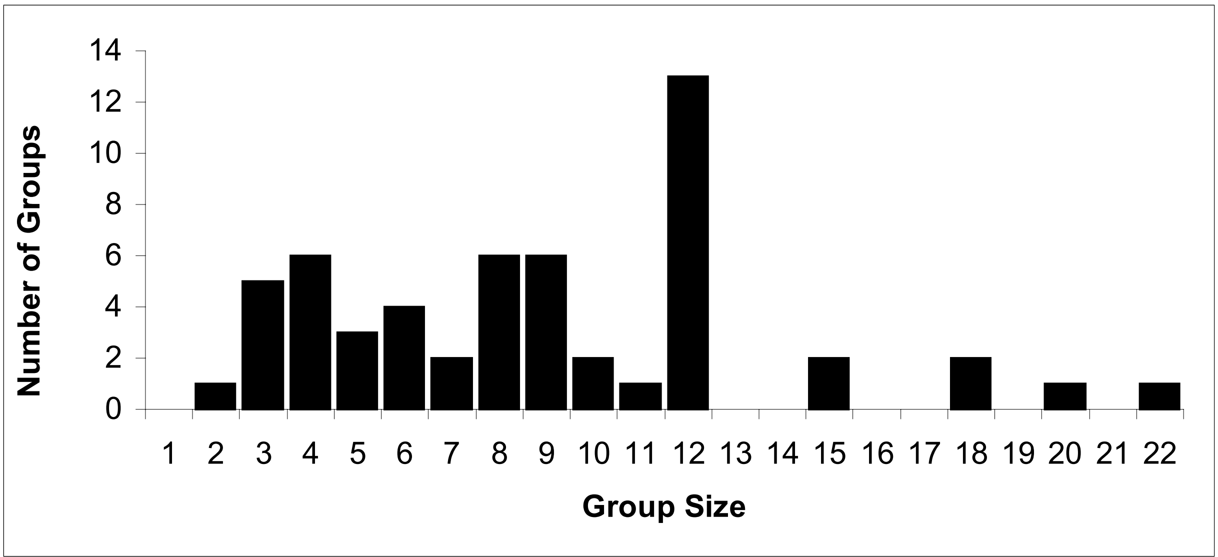
Table 3.1.
Age/Sex Classification within possible sub-populations (orca seen more than five times).

	Age / Sex of orca seen more than five times				
	Males				
Area Seen	Adult Male	Subadult Male	Female	Calf or Juvenile	Unknown
North-Island-only **(*n* = 17)**	**5**	**3**	**7**	**1**	**1**
North+South-Island **(*n* = 27)**	**12**	**3**	**10**	**1**	**1**
South-Island-only **(*n* = 6)**	**5**	**-**	**1**	**-**	**-**

Group Size

New Zealand orca tend to travel in small to medium sized groups (Fig. 3.1). Group size ranged from two to 22 individuals (mean = 4.5), of which 65% (*n* = 36) were comprised of eleven or less individuals, with groups of 12 (24%, *n* = 13) being the most common. Both the largest and smallest group sizes were recorded on only one occasion each. No photo-id was obtained of either of the two orca in the smallest group (although attempts were made over four hours). Therefore, it was not possible to ascertain if they were part of a larger group which had splintered for a short time frame.

Figure 3.1. Group size (n = 55), where the group size of 12 was the most common (n = 13)



Associations

Association Indices were calculated for the 50 orca seen more than five times (Appendix 1). The highest Association Index value was (0.93), which was calculated for four dyads. The next highest Indices (0.84) and (0.83) were calculated for one dyad each, and (0.80) was calculated for four dyads (Appendix 1). The mean Association Index value (for all 50 orca seen more than five times) was 0.25, the mode was 0.13 and the median was 0.18. However, it should be noted that this included 857 instances where there was no association at all (i.e., an Association Index of 0).

Fifteen orca with the highest Association Indices are presented in Table 3.2. Fourteen of these orca have interacted with 10 or more orca, who were also seen more than five times. The exception is a SAM, NZ44, who associated with 13 different orca, of which seven had also been sighted more than five times (Table 3.2). One adult female (NZ1) was seen with 48 other individuals from the total photo-identified population (n = 117), of which 21 were also seen on more than five occasions (Table 3.2). She associated more often with certain individuals than others, e.g., NZ3 (0.93), NZ48 (0.67), NZ49 (0.50), NZ99 (0.37), *cf* NZ6 (0.25) and NZ27 (0.13) (see Appendix 1). Although some individuals had a large number of associates, the Association Index values suggest that close associations are limited to as few as three other animals, e.g., NZ7 was seen with NZ8 (0.53), NZ9 (0.63), and NZ13 (0.67); NZ25 was seen with NZ44 (0.64), NZ88 (0.86) and NZ90 (0.67); and NZ44 was seen with NZ88 (0.75), NZ89 (0.75) and NZ25 (0.64).

Table 3.2. Individual orca and the number of associates.

Orca Catalogue Number	Total Number of Associates	Number of Associates who were also seen more than five times
NZ1	48	21
NZ3	43	20
NZ4	22	11
NZ5	30	11
NZ6	35	12
NZ7	33	10
NZ8	35	20
NZ9	31	10
NZ13	30	13
NZ24	27	15
NZ25	16	11
NZ26	15	10
NZ27	28	16
NZ44	13	7
NZ101	30	20

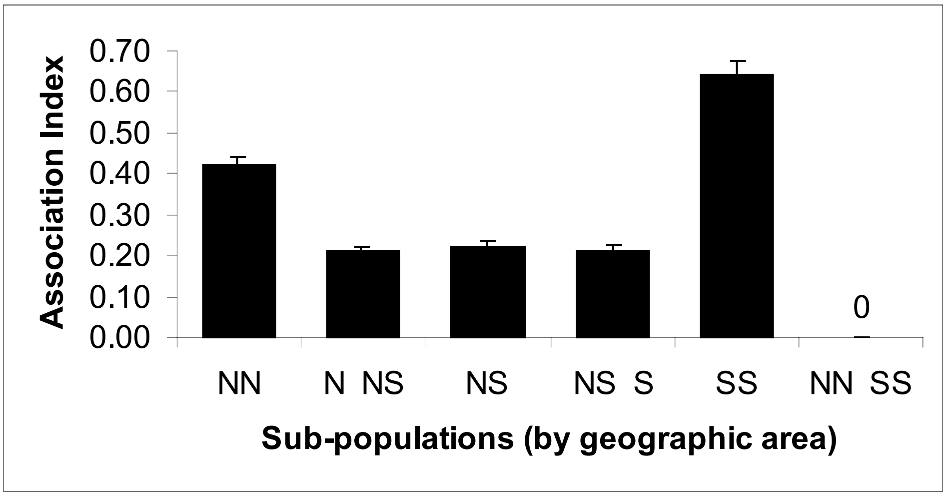
Some associations were long term, e.g., NZ1 (adult female) had been seen around the New Zealand coastline for 20 years, and had been sighted with NZ3 (adult male) on 19 occasions during 12 years. NZ15 (adult male) was first sighted in 1985 with NZ16 (adult female) and was resighted with the same female in 1994 (i.e., nine years later). NZ7 (adult male) was first sighted with NZ13 (adult female) in 1990 and was resighted with the same female nine times during seven years. NZ39 (adult female) was first sighted with NZ40 (adult male) in 1994 and NZ41 (adult male) in 1988. Four resightings with NZ40 and seven resightings with NZ41 occurred between the first sighting dates and 1997. Of note is that these examples of long term associations are between adult males and adult females. However, long-term associations do occur between adult females (e.g., NZ4 and NZ13, seen together eight times during four years; and NZ50 and NZ51, seen together six times during three years); adult males (e.g., NZ6 and NZ7, seen together 10 times during four years, and NZ3 and NZ6 seen together five times during three years); adult males and SAM's (e.g., NZ28 and NZ29, seen together six times during four years; and NZ89 and NZ44, seen together six times during three years), and adult females and SAM's (e.g., NZ4 and NZ9, seen together six times during four years).

Although no disassociation of groups were observed during this study, the smaller sub-groups encountered (e.g., NZ4, NZ5 & NZ6) within the larger varied groups were always comprised of the same animals. These small sub-groups may be seen with different sub-groups on subsequent encounters (e.g., the above sub-group have been sighted with another sub-group, comprised of NZ7 & NZ13 on 10 occasions, but have also been seen eight times without NZ7 & NZ13 present). Bigg *et al.* (1990) defined a pod as a group of individuals that travelled together at least 50% of the time. There were few instances in New Zealand where more than two orca were seen together at least 50% of the time and as their associations appeared to be, in many cases, more fluid (e.g., see Table 3.2), the term pod was not applied to any groups observed during this study.

Associations within two of the three proposed sub-populations were high (Fig. 3.2). Both the 'within North-Island-only' (NN) and 'within South-Island-only' (SS) were significantly higher than between the three sub-populations and 'within North+South-Island'(NS). Associations were low between North+South-Island and both the North-Island-only and South-Island-only sub-populations. As expected, no associations were recorded between the North-Island-only and South-Island-only sub-populations. Using the standard errors and the differences between means (McArdle 1987), it can be seen that there was a significant difference between the North-Island-only and the North+South-Island sub-populations. In addition, there was a significant difference between the South-Island-only sub-population and the North+South-Island sub-population. The Association Index within the supposed North+South-Island population (NS) was not significantly different to both of the between-population indices (N NS) and (NS S) (Fig. 3.2).

Figure 3.2. Mean (± SE) Association Indices

(within and between the three proposed sub-populations of New Zealand orca).



Key: NN = Associations within the North-Island-only sub-population

N NS = Associations between North-Island-only and North+South-Island sub-populations

NS = Associations within the North+South-Island sub-population

NS S = Associations between North+South-Island and South-Island-only sub-populations

SS = Associations within the South-Island-only sub-population

NN SS = Associations between the North-Island-only and South-Island-only sub-populations

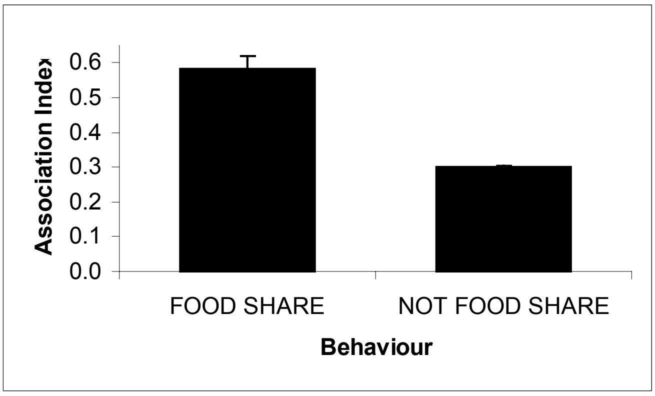
Food Sharing

Food sharing was seen between two or more orca on 85 occasions (elasmobranchs, n = 78; marine mammals, n = 5; fish, n = 2). Some instances involved more than two orca (maximum five orca – sharing a blue shark). Thirty two identified individuals have been seen food sharing. Of these, 15 were adult males, eight were SAM's and seven were females. Juveniles and calves were observed to food share but only two calves (NZ2 & NZ97) were identified. Forty seven other observations of food sharing were made, but it was not possible to establish who these individual orca were, due to various factors such as the food exchange occurring just below the surface.

Orca were observed to catch 86 rays (Visser, unpubl. data). On 85% (n = 73) of the times that a ray was caught, it was shared with another orca. Food sharing was seen more often between certain animals, e.g., NZ28 (adult male) and NZ29 (SAM) were observed taking 15 rays during one encounter. NZ28 caught eight rays and NZ29 caught seven rays and all were shared between the two animals. In another encounter NZ5 (female) and NZ7 (adult male) shared food five times. In addition, over a number of encounters, a SAM (NZ9) was seen to food share with an unidentified calf on six occasions, and NZ6 (adult male) was seen to food share with an unidentified calf on four occasions. No calves or juveniles were recorded catching rays so it may be assumed that they were being provisioned, but as pointed out in the methods, no distinction is made for this in the interpretation of the food sharing.

Food sharing showed a clear pattern; individuals who shared food had significantly higher (McArdle 1987) Association Indices than those who did not food share (Fig. 3.3).

Figure 3.3. Mean (± SE) Association Indices (for food sharing).



Circle Plot

By limiting the plotted Association Indices to 0.33 and above (and therefore removing occasional associations), there were a number of distinct groupings of orca visible, based on their associations on the circle plots (Fig. 3.4). For instance, the group of orca NZ39, NZ40, NZ41 and NZ42, who are only seen in the South Island (Fig. 3.4), had no strong associations with other individuals. Likewise, two North+South-Island groups were also clearly associating within their groups, but did not have strong associations with other orca (i.e., NZ25, NZ44, NZ88, NZ89 and NZ90 all had high associations as did NZ28, NZ29, NZ30 and NZ33).

However, there were some groupings of individuals that had more diffuse associations (Fig. 3.5). Although there was a grouping of North-Island-only animals who predominantly associated with each other (top right section of circle plot in Fig. 3.5), one orca in this group (NZ9, SAM) associated commonly within the group, but also associated with others from the North-Island-only sub-population. This group also contained two animals (NZ6 and NZ7, both adult males) who have been sighted off the South Island. Other orca from the North+South-Island sub-population (e.g., NZ1, NZ3, NZ27, NZ91 and NZ94 (males and females), bottom section of circle plot) have also been sighted with the North-Island-only animals, but only three associations between these five orca and North-Island-only animals were above 0.39, i.e., NZ27 (adult female) and NZ95 (SAM) (0.43), NZ94 (adult female) and NZ87 (adult female) (0.46) and NZ94 and NZ63 (adult female) (0.43).

Figure 3.5 Association Indices greater than 0.33 - most animals associated
(see text for explanation of values)

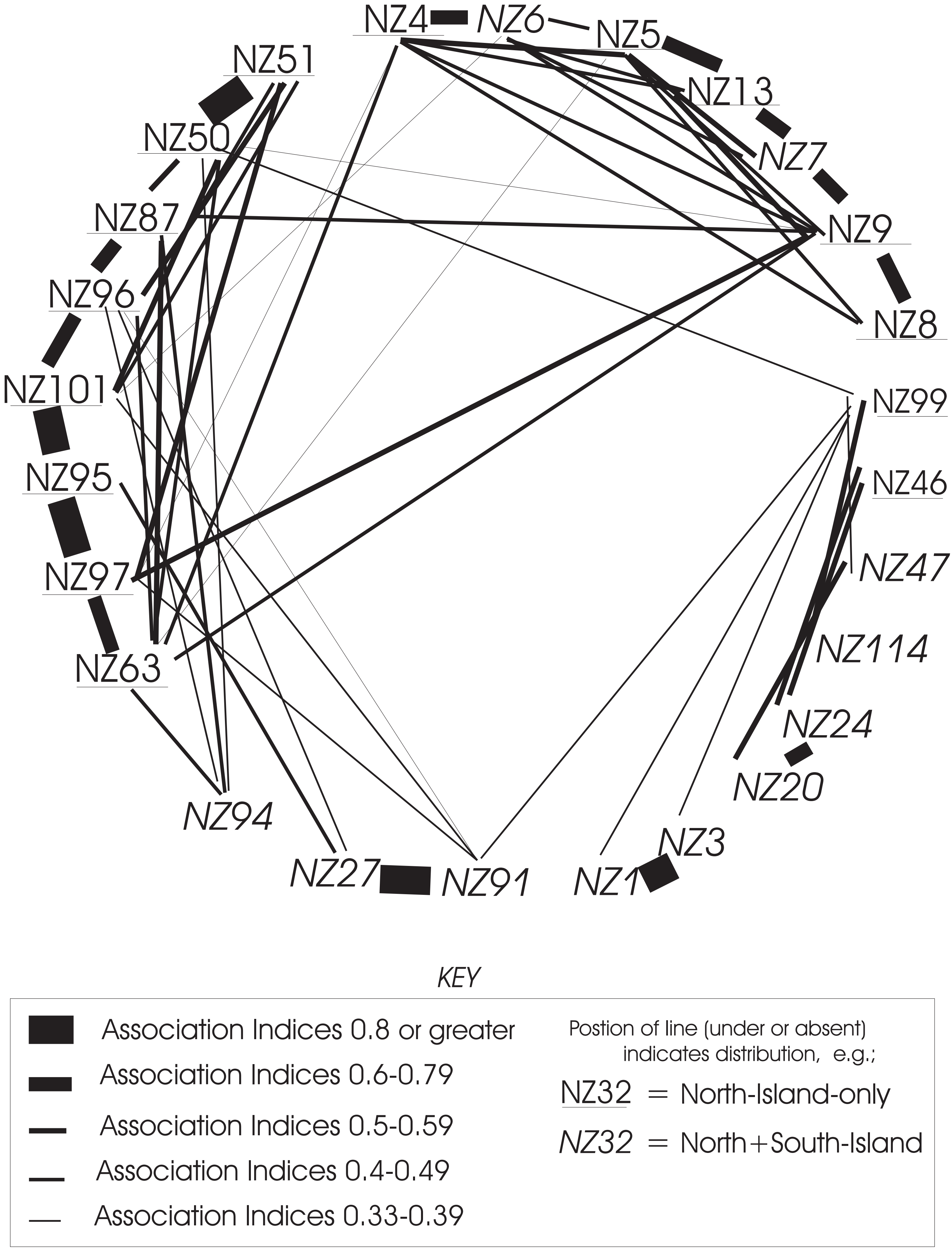
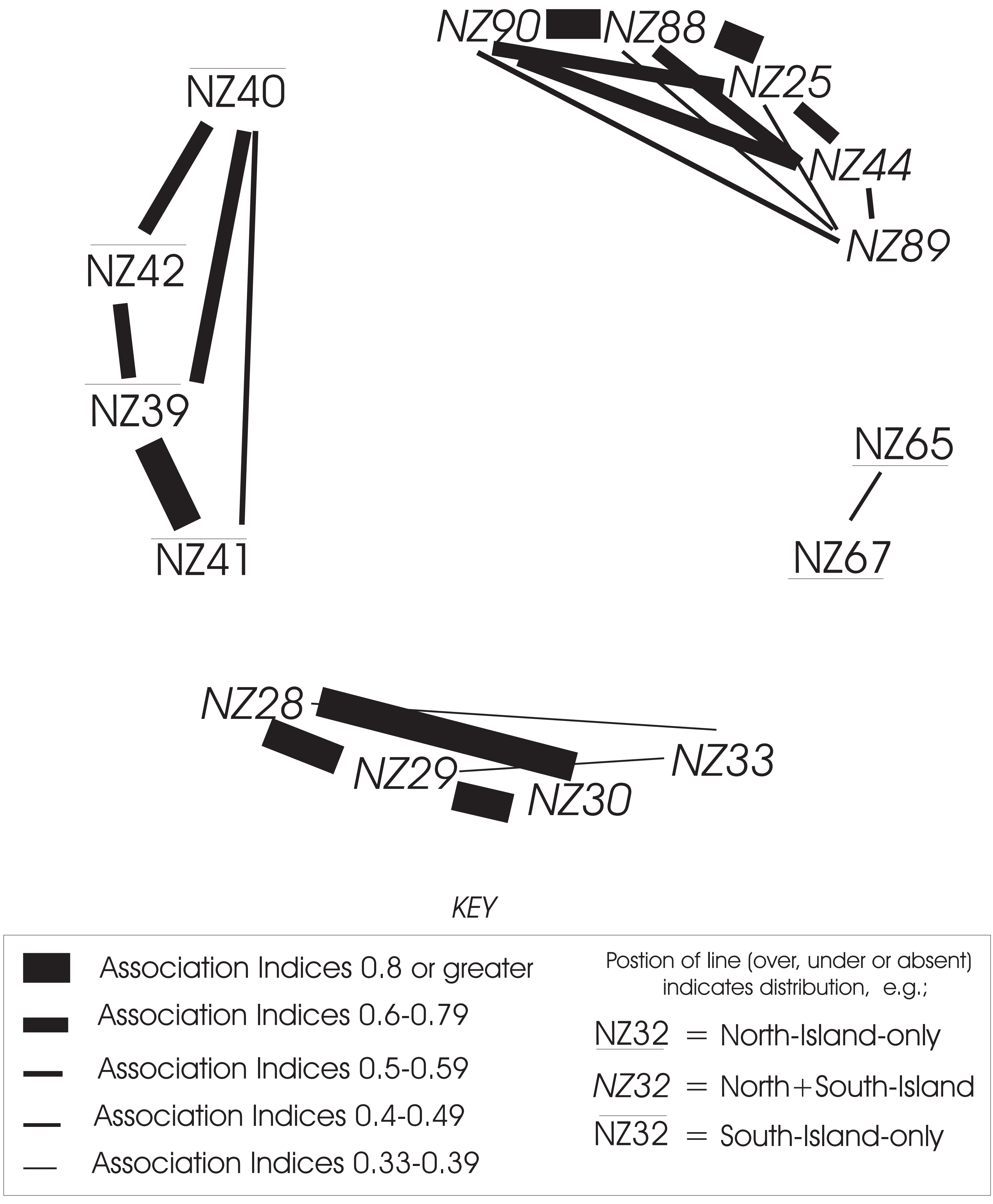


Figure 3.4 Association Indices greater than 0.33 - not all animals associated
(see text for explanation of values)



Discussion

Age/Sex Classification and Group Size

The 1:1 sex ratio for the total population (n = 117 individuals photoidentified) was similar to that reported for the overall PNW population of orca (Olesiuk *et al.* 1990). The apparent skewed sex ratios for the sub-populations may be an artefact of small sample sizes (maximum n = 27), or may reflect true biases, as has been found in some groups in the PNW (e.g., 'B1' pod, 6 males, 1 female, 1 unknown, 1 calf) (Ford *et al.* 1994).

Dispersal by young from their natal group is the usual way in which inbreeding is prevented. However, there are a few animals for which this has been discovered to be untrue. For instance, in New Zealand, the pukeko (*Porphyrio porphyrio melanotus,*) a native swamp hen, does not disperse and remains in the natal area to help raise subsequent clutches. Pukeko groups may have levels of over 70% inbreeding (Craig and Jamieson 1988). There have only been two species of mammals identified in which the young of either sex do not disperse from their natal group; the long-finned pilot whale (*Globicephala melas*), where this mating system has been described for the Faroe Island's population (Amos *et al.* 1991, Amos *et al.* 1993) and orca, where it has been described for the 'resident' population of the PNW (Bigg 1982, Ford *et al.* 1994, Matkin *et al.* 1998). The PNW 'transients' appear to follow both this system, and one where individuals may or may not disperse (Baird 2000, Ford and Ellis 1999). It is unclear yet whether New Zealand orca follow the 'resident' or 'transient' system of dispersal, or a combination of these two systems.

Calves and juveniles were seen more often than they were photo-identified, which may account for the apparently low number of young animals and the lack of identified calves within the South-Island-only sub-population. Regardless of whether they were photo-identified or not, nearly all groups encountered had calves with them and in all months of the year. This would suggest that there may be no specific mating or calving season as occurs in some other mammals. Statements given by Cawthorn (1991) about New Zealand orca, such as “calves and juveniles were associated with killer whales from January to March” and “killer whales with calves were observed from February through April” (Cawthorn 1992), may give the false impression of a calving season, as has been reported for bottlenose dolphins (Urian *et al.* 1996).

In New Zealand, group size tended to be 12 or less (89% of encounters). This compares to 52% for this size group in PNW ‘resident’ population of orca (Ford *et al.* 1994) whereas most (approximately 97 %) ‘transients’ tended to travel in small groups (2- 6), (Ford and Ellis 1999). The largest group of ‘transients’ recorded in the PNW by Ford and Ellis (1999) was 22, the same as the largest group size found for the New Zealand population. In Argentina, the most common group size was two (range 1-7) (Hoelzel 1991). The smallest group size recorded in New Zealand was one instance of two animals travelling together. No photo-id was obtained for either of these animals, so it was not possible to ascertain if they were part of a larger group that had splintered for a short time, as has been seen for orca in the PNW (Ford *et al.* 1994). The next group size (i.e., three orca) was seen on five different occasions. There were no encounters with single orca during this study, but Ford and Ellis (1999) recorded just over 10% of their encounters with PNW ‘transients’ as single animals, and Baird and Dill (1996) recorded 35% with the same population. Hoelzel (1991), in his study of the Argentina orca, commented that two adult males were observed hunting as individuals, but did not state for what percentage of observations.

In orca, group size appears to be a function of foraging strategies and prey. Hoelzel (1991) compared the group sizes of orca that attacked 20 different marine mammal prey species (including large whales, other cetaceans and pinnipeds) and found the mean number of orca was seven. In this study in Argentina, Hoelzel (1991) also found the most common group size was two and the most common prey was the Southern sea-lion (*Otario flavenscens*). Baird (1994) and Baird and Dill (1996) proposed that the smaller group sizes of PNW ‘transient’ orca was a reflection of their hunting style ('stealth') and prey (typically harbour seals) (*Phoca vitulina*). Ford *et al.* (1998) noted a significant correlation between the group size and the size of the prey, where generally, the larger the marine mammal attacked, the larger the orca group size. However, this is only up to the optimum group size. Baird and Dill (1996) explained that if the group size was larger, it may require more coordination (e.g., acoustically; although typically, 'transients' are very quiet when hunting), or the larger group sizes may be more obvious to the marine mammal prey, such as seals and dolphins. They also pointed out that in terms of energy requirements when hunting for harbour seals (the most frequently attacked marine mammal in their study), the optimal foraging group size was three, and this was the most frequently encountered 'transient' group size (Baird and Dill 1996). Larger aggregations of these smaller groups may be a function of hunting for larger prey, the social aspect of joining with other groups (e.g., mating), or to protect very young members of the group (Baird and Dill 1996).

PNW 'resident' orca typically hunt for salmon, their group sizes are much larger (typical group size, $n = 20$) (Bigg 1982, Bigg *et al.* 1987, Ford *et al.* 1998) and they tend to be more acoustic than the 'transients' (Ford 1989, Ford 1991). In Norway, the median group size was 15 and the main food in the fjords is schools of herring (*Clupea harengus*) (Similä *et al.* 1996). Similä *et al.* (1996) noted that the schools of herring recorded were small (2.5 - 7 m diameter), but they did not comment if larger groups of orca were found around larger schools of herring.

In New Zealand, the typical group size (i.e., 12 orca) falls between the typical group size of PNW 'transients' ($n = 3$) and 'residents' ($n = 20$). The most common prey items consumed by New Zealand orca, i.e., rays (at between 70 and 100 cm disc width, approximately 20-40 kg in weight - NIWA, unpubl. data), also fall between the size ranges of prey items for the piscivores and carnivores, e.g., salmon 1.7 – 14.7 kg (Ford *et al.* 1998), Southern sea-lion pups 50-70 kg (Hoelzel 1991) and harbour seals 59 – 73 kg (King 1983). Therefore, group size in New Zealand orca may be a function of prey size and type.

Association Indices

Association patterns in delphinids range from the fluid fission-fusion society such as that found in the spinner dolphin (Herman 1980, Norris and Dohl 1980, Östman 1994), to the group stability found in orca (Bigg *et al.* 1987, Ford *et al.* 1994). Investigations of the PNW populations of orca have provided detailed descriptions of their associations and shown a cascading hierarchy, where the individuals associate at differing levels; from always seen together in stable tight groups, to groups that are never seen together (Baird 1999, Bigg 1982, Ford and Ellis 1999, Ford *et al.* 1994). This range of differentiation is common in social mammalian species (Goodall 1991, Schaller 1972).

An Association Index is used to calculate the relative amount of time an individual spends with another, taking into account the number of times it is also sighted without the other animal (Cairns and Schwager 1987). The main criterion used by Ford and Ellis (1999) to determine the social identity of 'transient' PNW orca was their patterns of association. All orca that could be linked together through their associations formed what they termed a 'community' (Ford and Ellis 1999), which appears to be similar to the sub-populations found in New Zealand. Baird and Dill (1995) found that 'transient' pods who foraged in similar ways ('open-water' *vs.* 'nearshore') were more likely to be found associating with each other than with pods that foraged in dissimilar ways.

In New Zealand, some orca showed strong associations with others, e.g., 10 dyads had an Association Index of (0.80) or higher, suggesting that certain individuals may form small, stable groups (perhaps of only two or three animals). These appear to endure over time (e.g., NZ1 and NZ3, sighted together 19 times during 12 years). However, orca who show these strong associations may also have been seen with many other orca (up to 48 other individuals, see Table 3.2), for which they have either medium or low Association Index values (as low as 0.06 –

however, some of these animals with whom they have low associations have been photographed less than five times, which may bias the results). This pattern suggests that these small stable groups may associate with similar structured groups more frequently than other groups (e.g., NZ4, NZ5 & NZ6 are frequently seen with NZ7, NZ13 & NZ101).

Observations of the PNW population showed that when 'resident' pods who had been travelling together disassociated, individuals consistently returned to their own pod (Balcomb *et al.* 1982). Although no disassociation of groups has been observed during this study, the smaller sub-groups have always been comprised of the same animals, suggesting that a similar situation occurs in New Zealand waters. These small sub-groups may be seen with either the same or different sub-groups on subsequent encounters. Within these sub-groups the associations are strong, but between the sub-groups the associations vary widely. I propose that the term 'network' would best describe the associations that these small New Zealand sub-groups form.

Comparing the mean Association Index values of the three possible geographic sub-populations suggests that this geographic division does not fully describe the population structure. As could be expected, should the hypothesis of separate North and South populations be correct, there is no associations between these two populations. However, the definitions are not so clear for the proposed North+South-Island sub-population. The mean Association Index within the proposed North+South-Island sub-population is as low as that between it and the other more likely sub-populations (i.e., North-Island-only and South-Island-only). This suggests that the proposed North+South-Island sub-population is likely to have further sub-divisions. More research into associations and distribution is required to resolve this issue and to understand the likely population structure for the New Zealand orca.

Food Sharing

Hoelzel (1991) suggested that food sharing or provisioning may be a function of kin groups, or inclusive fitness (when provisioning related young). Although the two males in his study were related, he commented that it was not so clear why they might hunt together, when their average net rate of intake was greater when they hunted alone. He offers four factors that might be important: (1) high-quality foraging sites are rare, (2) the cost of competing over high quality sites could be very high, (3) the animals are closely related, (4) individuals in the group obtain sufficient food to sustain them.

Looking at these four factors in the context of a similar New Zealand situation where two males (NZ28 adult male, and NZ29 SAM) also hunted together and shared food (see '*Predictable Behaviour during Foraging'* in Chapter Four), it would seem that (1) there were numerous high-quality foraging sites for rays (Visser 1999), (2) the cost of competing would therefore not be an issue, as competition would not be necessary (although see scarring on individuals in Visser, 1998), (3) it is unknown if the animals are closely related, however, they have a particularly high Association Index (0.93) and were sighted together seven times during three years, suggesting a long term association pattern. High associations over extended periods in other studies have indicated relatedness in orca (Bigg *et al.* 1987, Ford and Ellis 1999, Ford *et al.* 1994, Matkin *et al.* 1998). Looking at factor (4) requires a little more depth. If we use the calculation of the number of rays taken in one five-hour unit of observation (n = 15, which equals approximately 300 – 600 kg) and assume; this represented all, or nearly all, prey consumed that day; and that the food was shared equally between the two animals (i.e., 150 – 300 kg per orca); and use then the assumption that approximately 4% of the body weight was the required daily food intake for an orca (Hoyt 1984, Kastelein *et al.* 2000); and that the orca body weight was between 6 – 9 tonnes (Carwardine 1995, Hoyt 1984); then the rays consumed would be 1.6 – 3.3 % of body weight. Therefore it is possible that the number of observed rays caught was less than sufficient to provision both animals.

Combining all these factors and assumptions, it seems possible that factor (3) (i.e., relatedness), is the factor Hoelzel (1991) suggested which is most likely to contribute towards these two New Zealand males hunting together. However, genetic sampling to look at relatedness of these two animals (and further work with orca of known relatedness) could evaluate this.
Thirty two identified orca were seen to share food and their mean Association Index was significantly higher than those orca that did not share food (Fig. 3.3). Animals who shared food had an average Association Index that was nearly double that found for animals that did not share food, suggesting that Association Indices may be indicative of a range of affiliative behaviours.

Food sharing in New Zealand occurred on 85% of observed ray captures which is considerably higher than that found for the PNW orca, who shared 51% of the kills (Baird and Dill 1995). Baird and Dill (1995) explained that prey sharing in their study was difficult to observe and, in many cases, it would not have been possible to observe sharing of prey even if it occurred, but they do note that they recorded what they assumed to be a high proportion of all kills.

Circle Plot

The grouping of the orca in the circle plot suggests that the proposed sub-populations comprise of a mix of individuals who associate variously among themselves and with others. Overall, South-Island-only and North-Island-only individuals largely associated among individuals with similar ranges. However, it is important to realise that the North-Island-only sub-population is made up of partially separate groups who do not have strong associations with other orca from the same sub-population. These association patterns help confirm the sub-population divisions. The North+South-Island sub-population appears far more heterogeneous than the other two sub-populations. Some individuals (e.g., NZ25, NZ44, NZ88, NZ 89 and NZ90) predominantly associate with each other whereas other individual North+South-Island orca associate more widely (e.g., NZ27, NZ91, NZ94). This helps explain the low means and high variance of Association Indices within this proposed sub-population.

Some of the orca currently designated as North-Island-only may be North+South-Island animals, but have not yet been photographed in the South Island. For example, the North-Island-only orca NZ4, NZ5, NZ8, NZ9 and NZ13 all have strong links directly or indirectly with NZ6 and NZ7 who have both been sighted off the South Island (see Fig. 2.16 & Fig. 2.18). However, these two orca have only been sighted off the South Island once and as both are adult males, their sightings in the South Island may be linked to temporary dispersal for breeding.

Although NZ1 (adult female) had a large number of overall associates (Table 3.2, 48 associations), in the circle plot (Fig. 3.5) she was only strongly associated with two other orca. This may reflect her close association with a small core group and loose affiliation with a larger group, supporting the concept of a 'network', as described above.

Additional support for the proposed sub-populations and their potential non-mixing, comes from preliminary results from a mtDNA test. Two tissue samples from orca from the North Island, New Zealand, were analysed for relatedness and found to differ by 1bp out of 995bp from the mtDNA control region (Hoelzel and Visser, unpubl. data). While this does not appear to be a high level of differentiation, haplotypes in orca populations in other parts of the world tend to be fixed, i.e., each orca shares the same haplotype (Hoelzel *et al.* 1998), therefore even a 1bp difference indicates the two orca were from different matrilines and probably from different populations (R. Hoelzel, pers. comm.). As both samples were taken from locations only approximately 120 km apart (and collected in 1997 and 1998), the hypothesis that some members of the North-Island-only population do not mix with the North+South-Island population is not unrealistic.

Summary

Further investigations into the relatedness of individuals frequently seen together will help to define the substructure of observed groups, but based on the information gathered from various overseas studies, e.g., behavioural observations, Association Indices and genetic evidence (Bain 1988, Ford 1991, Hoelzel 1991, Matkin *et al.* 1998, Stevens and Duffield 1990), it appears that orca who food share would be more likely to be related than those who do not food share. It is highly unlikely that the associations shown here are random, as clumped or grouped dispersion and associations in animals is more common (Brown 1975).

Conservation management of New Zealand orca is suggested because of the small overall population size. Whether attention is needed for each proposed sub-population is unknown because there is insufficient information to determine the degree of gene exchange. The existence of a ‘loose’ North+South-Island group means that gene exchange between all orca in New Zealand is possible, therefore the population may be a single meta-population. However, the results presented here, together with the preliminary results of the mtDNA test, suggest that there may be more than one genetic sub-population in New Zealand waters. Although only one migrant per generation is considered enough to maintain genetic diversity, this may not be enough for a natural population (Mills and Allendorf 1996). Combining further behavioural, association and genetic information would assist in resolving these issues.

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Appendix 1. Association Indices of orca seen more than five times (n = 50).
Orca catalogue number (NZ) is across the top and down the left side

	NZ1	NZ3	NZ4	NZ5	NZ6	NZ7	NZ8	NZ9	NZ10	NZ13	NZ14	NZ15	NZ16	NZ19	NZ20	NZ23	NZ24	NZ25	NZ26	NZ27	NZ28	NZ29	NZ30	NZ32	NZ33	NZ39	NZ40	NZ41	NZ42	NZ44	NZ45	NZ46	NZ47	NZ50	NZ51	NZ63	NZ65	NZ67	NZ87	NZ88	NZ89	NZ90	NZ91	NZ94	NZ95	NZ96	NZ97	NZ99	NZ101	NZ114
NZ1	X	0.93	0.12	0.16	0.25	0.09	0.11	0.17	0	0.11	0	0	0.6	0	0.07	0	0.12	0	0.18	0.13	0.07	0.07	0.07	0.07	0.07	0	0	0	0	0.06	0.09	0	0.07	0.21	0.21	0.2	0	0	0.14	0	0.13	0.13	0.13	0.21	0.15	0.07	0.15	0.37	0.07	0
NZ3		X	0.13	0.17	0.27	0.09	0.12	0.18	0	0.12	0	0	0.06	0	0.07	0	0.13	0	0.2	0.14	0	0	0	0.08	0.08	0	0	0	0	0.07	0.09	0	0.08	0.23	0.24	0.22	0	0	0.15	0	0.07	0	0.14	0.24	0.17	0.08	0.17	0.33	0.08	0
NZ4			X	0.5	0.63	0.39	0.46	0.46	0.27	0.44	0.27	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.15	0	0.21	0.11	0.4	0.13	0.12	0.32	0	0	0	0	0.22	0	0.04	0.35	0	0.32	0.13
NZ5				X	0.48	0.55	0.4	0.4	0.11	0.65	0.32	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0.17	0.18	0.33	0.1	0	0.17	0	0	0	0	0.09	0	0.29	0.29	0.1	0.26	0
NZ6					X	0.49	0.35	0.45	0.14	0.44	0.21	0	0	0	0	0	0.05	0.05	0.09	0	0	0	0	0	0	0	0	0	0	0.06	0.07	0.07	0	0.24	0.19	0.41	0.13	0.08	0.3	0	0	0	0	0.19	0	0.32	0.32	0.06	0.36	0.07
NZ7						X	0.53	0.63	0.15	0.67	0.15	0.06	0	0.13	0	0	0	0.06	0	0.06	0	0	0	0	0	0	0	0	0	0	0	0.08	0	0.19	0.13	0.25	0.14	0.13	0.19	0	0	0	0	0.13	0	0.28	0.28	0.07	0.26	0
NZ8							X	0.71	0.24	0.48	0.24	0.08	0	0.09	0.09	0.09	0.08	0.08	0	0	0	0	0	0.11	0.11	0	0	0	0	0	0	0.13	0.1	0.19	0.1	0.18	0.22	0.13	0.19	0	0	0	0	0.1	0	0.21	0.32	0	0.19	0.12
NZ9								X	0.24	0.55	0.12	0	0	0.18	0.21	0	0	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0	0.38	0.3	0.45	0.22	0	0.48	0	0	0	0	0.3	0	0.42	0.53	0.11	0.38	0.12
NZ10									X	0.33	0.33	0	0	0.18	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0	0	0
NZ13										X	0.33	0	0	0.09	0	0	0	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.18	0.19	0.35	0.11	0	0.18	0	0	0	0	0.1	0	0.3	0.3	0.1	0.27	0
NZ14											X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NZ15												X	0.25	0.11	0.11	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NZ16													X	0.18	0.18	0.18	0.08	0.08	0.16	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09	0	0	0.09	0	0	0	0	0	0	0
NZ19														X	0.13	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0	0.18
NZ20															X	0.13	0.74	0	0	0.11	0	0	0	0	0	0	0	0	0	0	0	0	0.53	0	0	0	0	0	0	0	0	0	0.12	0.14	0.17	0	0	0.15	0	0.18
NZ23																X	0.11	0.1	0.21	0.11	0.13	0.13	0.13	0.15	0.15	0	0	0	0	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0.12	0	0	0	0	0	0	0
NZ24																	X	0	0.09	0.1	0	0	0	0	0	0	0	0	0	0	0.29	0.56	0	0	0	0	0	0	0	0	0	0	0.1	0.12	0.13	0	0	0.13	0	0.14
NZ25																		X	0.09	0	0	0	0	0	0	0	0	0	0	0.64	0	0	0	0	0	0	0	0	0	0.86	0.4	0.67	0	0	0	0	0	0	0	0
NZ26																			X	0.1	0	0	0	0	0	0	0	0	0	0.1	0.14	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0
NZ27																				X	0.11	0.12	0.12	0.13	0.13	0	0	0	0	0	0	0	0.12	0.12	0.13	0	0.14	0	0	0	0.11	0	0.84	0	0.43	0.33	0	0.13	0	0
NZ28																					X	0.93	0.93	0.32	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0.12	0	0	0	0	0.15	0	0
NZ29																						X	0.93	0.17	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.27	0	0.13	0	0	0	0	0.17	0	0
NZ30																							X	0.17	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.27	0	0.31	0	0	0	0	0.17	0	0
NZ32																								X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.14	0	0	0	0	0	0	0
NZ33																									X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.14	0	0	0	0	0	0	0
NZ39																										X	0.67	0.93	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NZ40																											X	0.55	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NZ41																												X	0.73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NZ42																													X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NZ44																														X	0.15	0	0	0	0	0	0	0	0	0.74	0.56	0.75	0	0	0	0	0	0	0	0
NZ45																															X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NZ46																																X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NZ47																																	X	0.29	0.31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NZ50																																		X	0.93	0.4	0	0	0.57	0	0.13	0	0.13	0.31	0.18	0.67	0.67	0.33	0.57	0.2
NZ51																																			X	0	0	0	0.46	0	0.14	0	0.13	0.33	0.2	0.55	0.55	0.36	0.46	0.22
NZ63																																				X	0.17	0	0.53	0	0	0	0	0.43	0	0.46	0.62	0.15	0.4	0.18
NZ65																																					X	0.4	0	0	0	0	0	0	0	0	0	0	0	0
NZ67																																						X	0	0	0	0	0	0	0	0	0	0	0	0
NZ87																																							X	0	0	0	0	0.46	0	0.67	0	0	0.17	0.2
NZ88																																								X	0.47	0.8	0	0	0	0	0	0	0	0
NZ89																																									X	0.57	0.12	0	0	0.17	0	0	0.31	0
NZ90																																										X	0	0	0	0	0	0	0	0
NZ91																																											X	0	0.46	0	0	0.14	0	0
NZ94																																												X	0	0.36	0.36	0.36	0.34	0.22
NZ95																																													X	0.33	0	0.22	0	0
NZ96																																														X	0.8	0.2	0.83	0.25
NZ97																																															X	0.2	0.67	0.25
NZ99																																																X	0.17	0
NZ101																																																	X	0.5
NZ114																																																		X

CHAPTER FOUR

Foraging behaviour and diet of orca (*Orcinus orca*) in New Zealand waters

Abstract

Orca (*Orcinus orca*) feed on a wide range of prey and in some areas sympatric populations show different foraging strategies and prey preferences (foraging eco-types). Twenty four different species of prey have been recorded in the New Zealand orca diet. Of these, ten have not been recorded elsewhere. The prey consists of four types; rays, sharks, fin-fish and cetaceans (pinnipeds have not been identified as a prey source). Foraging strategies were different for each prey type, with Benthic Foraging for rays being the most diverse used in New Zealand. Food sharing was observed for all prey types. Rays were the most common food type, by number of individual orca foraging and by the number of rays taken. Benthic Foraging appears to be a unique foraging strategy for orca worldwide. One of the three proposed New Zealand sub-populations of orca appears to be generalist or opportunistic foragers, feeding on all four prey types, another sub-population slightly less so, feeding on three prey types and the third sub-population appears to be a specialist forager, taking only one prey type (cetaceans). These separations in foraging eco-types may help to define the proposed sub-populations and suggest areas where management resources can be concentrated.

Introduction

Orca Diet - Worldwide

Orca (*Orcinus orca*) as a species are opportunistic feeders, however, within populations they often specialise in foraging methods and prey. Hoyt (1984), Jefferson *et al.* (1991), Matkin and Saulitis (1994), Fertl *et al.* (1996), Similä *et al.* (1996), Ford and Ellis (1999) and Saulitis *et al.* (2000) all discuss the diet of orca. Prey species are diverse and include terrestrial animals, such as moose (*Alces alces*), deer (unknown species) and the freshwater river otter (*Lutra canadensis*) (Ford and Ellis 1999, Ford *et al.* 1998, Matkin *et al.* 1999a). It also includes assorted marine organisms such as jellyfish (Similä *et al.* 1996), cephalopods (Berzin and Vladimirov 1983, Ford *et al.* 1998, Matkin and Saulitis 1994, Nishiwaki and Handa 1958, Rice 1968), turtles (Caldwell and Caldwell 1969, Esquivel *et al.* 1993, Sarti *et al.* 1994), walrus (*Odobenus rosmarus divergens*) (Fay, 1982) and dugong (*Dugong dugon*) (Anderson and Prince 1985). Seabirds (penguins in particular in the Southern Hemisphere) have been recognised as part of the diet for various populations (Castello *et al.* 1994, Condy *et al.* 1978, Guinet 1992, Matkin and Saulitis 1994, Odlum 1948, Similä *et al.* 1996). More typically, the diet of orca consists of marine animals such as fin-fish, elasmobranchs, pinnipeds and other cetaceans (e.g., Budylenko 1981, Fertl *et al.* 1996, Ford and Ellis 1999, Ford *et al.* 1998, Jefferson *et al.* 1991, Matkin and Saulitis 1994, Similä *et al.* 1996, Visser 1999a, Visser 1999b, Yukhov *et al.* 1975).

Foraging strategies have proved to be just as diverse as the prey types and have included intentional stranding to capture pinnipeds (Guinet 1991, Hoelzel 1991), ambushing penguins (Condy *et al.* 1978, Guinet 1992), feeding in association with fisheries (Dahlheim 1999, Northridge 1991, Visser 2000, Yano and Dahlheim 1995), hunting as individuals for fish (Bigg *et al.* 1987), and coordinated hunting for sharks (Fertl *et al.* 1996), rays (Visser 1999a), herring (Similä and Ugarte 1993), pinnipeds (Baird 1994, Guinet and Bouvier 1995, Hoelzel 1991, Smith *et al.* 1981), whales (Goley and Straley 1994, Jefferson *et al.* 1991, Visser 1999b) and dolphins (Baird and Dill 1995, Constantine *et al.* 1998, Jefferson *et al.* 1991, Visser 1999b).

In waters off the Pacific North West seaboard of North America (PNW), sympatric populations of orca specialise in foraging strategies and prey selection (Ford *et al.* 1998, Saulitis *et al.* 2000). Although hunting in the same areas, they do not mix, have different foraging strategies and appear to have divergent prey preferences that do not overlap. There are three 'forms' of orca found in the area, two of which are well studied and have been termed the 'resident' and the 'transient' types. The 'resident' type forages almost exclusively on fin-fish (and never takes marine mammals) and the 'transient' type forages almost exclusively on marine mammals and birds (and never takes fin-fish) (Ford *et al.* 1998, Saulitis *et al.* 2000). A similar scenario has been proposed for Antarctic orca, where two types of orca have been described which have a sympatric distribution but are morphologically different and hunt for slightly overlapping, but mainly different prey types (Berzin and Vladimirov 1983). It has been suggested that these divergent prey preferences may be found in other populations of orca around the world (Ford *et al.* 1998). Different sub-populations of orca have been found in New Zealand, and it may support the definition of, and distinctions between, the sub-populations if it was established they had different diets.

Understanding diet, and by association, habitat use, is important when population sizes are small. This information is valuable for management when there is a conservation requirement. Not only will identification of different foraging strategies and food preferences (foraging eco-types) help to identify and define potential sub-populations, it will also help to highlight where management effort would be most beneficial. For instance, human use of both land and sea has the potential to negatively affect marine mammals such as orca. This usage may directly reduce foraging habitat via construction programs such as harbour reclamation. In addition, land-based production, modification of the landscape, chemical applications to farms and run-off from roads and cities, and untreated factory and effluent emissions (released into waterways) are all capable of contributing pollutants to the marine environment which can create general degradation of foraging habitat. All of these contaminants can bioaccumulate through the food chain and may affect apex marine predators (e.g., orca) through aspects such as reproductive deficiencies and immuno-suppression (e.g., Baird 2000, Colborn and Smolen 1996, Slooten and Dawson 1995). Overfishing is an issue in all oceans of the world, and this may reduce food supplies for apex predators, if they rely directly, or indirectly, on commercial species. Interactions between fishers and orca may become negative if a conflict of interest is perceived (e.g., Visser 2000).

Orca Diet - New Zealand

Baird (1999) discussed limiting factors affecting orca in the PNW and divided them into two broad categories; Natural Mortality and Anthropogenic Influences. Under the anthropogenic category he lists two conservation problems as critical – the effects of pollutants and the reduction of prey due to human activities. Slooten and Dawson (1995) identified issues of conservation threats to marine mammals in New Zealand. The issues they noted that affect orca in relation to their diet are; pollution (through bioaccumulation via prey) and fisheries interactions (through by-catch and potentially reduced food supplies).

This chapter describes the diet and foraging strategies of New Zealand orca. It investigates whether the suggested sub-populations in New Zealand have different foraging strategies and hence have behavioural differences in addition to differences in distribution and social links. The chapter also investigates associated management issues that relate to diet and foraging areas.

Methods

Following a report, orca were encountered and behavioural observations recorded (see Chapter 2 for details). Incidences of predation (or attempts at predation) and prey type were determined by observations of the prey species in the mouth of the orca, prey remains at the surface or subsurface, prey leaving the water (e.g., having been 'tossed' out of the water or voluntarily leaving), prey species observed attempting to escape and birds following the orca and picking up prey remains. Prey foraging strategies were described and grouped according to prey type.

As it is not possible to distinguish between provisioning and food sharing based on size alone (e.g., adult orca have been observed taking food to other adult orca), no differentiation was made between the two (i.e., provisioning and food sharing) and both have been termed food sharing.

Stomach contents from two stranded (dead) orca were examined for prey remains during this study. Seven orca were taken in New Zealand waters by a Russian whaling vessel, between 1961 and 1979, and stomach contents recorded (Mikhalev *et al.* 1981).

Whilst following groups of orca, acoustical recordings were made wherever possible, including whilst the orca were foraging. This was done using an 'Offshore Acoustics' hydrophone system which utilises a lead-zirconate piezoelectric active element with a low-noise preamplifier. It is omnidirectional and has an operating range of approximately 10 km in calm conditions and is a sensitive system (-149 dB re 1 μPA). The frequency response is from 5Hz to 25 kHz, which covers the hearing range of humans (15Hz to 16kHz) and the sound range produced by most marine mammals (Ford 1994).

Results

Foraging strategies for New Zealand orca have been described in detail (Constantine *et al.* 1998, Visser 1999a, Visser 1999b, Visser 2000, Visser *et al.* 2000) and include cooperative hunting for rays, sharks and cetaceans and removing fish off longlines. A wide range of orca prey species (*n* = 24) have been recorded (Table 4.1), of which ten have not been reported elsewhere.

Elasmobranchs (sharks, rays and skates)

New Zealand orca have been observed feeding on elasmobranchs since at least 1992 (Visser 1999a). Typically they feed on eagle (*Myliobatis tenuicaudatus*), long-tailed (*Dasyatis thetidis*) and short-tailed (*Dasyatis brevicaudatus*) rays (Fertl *et al.* 1996, Visser 1999a), but have also been observed feeding on five other species of elasmobranchs (Table 4.1).

'Benthic Foraging' (Visser 1999a) is a method used by New Zealand orca to hunt for rays on the sea floor. Benthic Foraging may include orca 'digging' (using their rostrums) in the substrate for rays, or cooperatively catching rays on the seafloor. It includes 'milling' where individuals repeatedly dive in varying directions, 'head stands' (vertically inverted with tail thrashing), turning on their sides to navigate shallow areas, stirred up sediment, surfacing with mud on their rostrum, tossing of prey, stranding whilst pursuing prey, large underwater bubble releases (termed 'bubble blows'), holding prey by the tail, pinning prey against the bottom (see Visser 1999a and Table 4.2 for further explanations) and flipping rays upside down (Visser unpubl. data).

Benthic Foraging appears to be a successful method of foraging, as more rays were taken in one day by New Zealand orca (*n* = 15) (Visser 1999a) than reported in the literature over a 40 year period (*n* = 11) (Fertl *et al.* 1996). Food sharing occurs for 85% of the ray captures (Chapter 3) and although no distinction is made between provisioning and food sharing, adult orca (both male and female) have been observed taking food to calves and juveniles. During food sharing of rays, one orca may hold a ray whilst another orca removes the wings (e.g., see Fig. 4.1, note bite mark in head of ray where one orca held the ray and the other removed the wing). Usually the liver of the ray is not eaten (Fig. 4.2).

Figure 4.1.

Orca prey remains (eagle ray, *Myliobatis tenuicaudatus*) with one wing removed by orca.

Figure 4.2. Liver remains from unidentified ray, recovered during orca Benthic Foraging.

Table 4.1. Summary of species as prey items for New Zealand orca, and new species added to the known prey items of orca worldwide

Prey Type	Prey taken in NZ, but also recorded elsewhere	Species only recorded in New Zealand	Total # of species in NZ	Source
Coelenterates	salp, unidentified species		One	This chapter
Molluscs	octopus, unidentified species		One	This chapter
Elasmobranchs	blue shark, *Prionace glauca* basking shark, *Cetorhinus maximus*	short tailed stingray, *Dasyatis brevicaudatus* long tailed stingray, *Dasyatis thetidis* eagle ray, *Myliobatis tenuicaudatus* torpedo ray, *Torpedo fairchildi* mako shark, *Isurus oxyrinchus* school shark, *Galeorhinus galeus*	Eight	Visser 1999a, Visser *et al.* 2000, Fertl *et al.* 1996, S. Dawson, pers. comm., This chapter
Fin-Fish	yellow fin tuna, *Thunnus albacares* sunfish, *Mola mola* 2 unidentified species	bluenose, *Hyperoglyphe antarchia* kahawai, *Arripis trutta*	Four	Visser 2000, This chapter
Cetaceans	common dolphin, *Delphinus delphis* bottlenose dolphin, *Tursiops truncatus* sperm whale, *Physeter macrocephalus* pilot whale, *Globicephala melas* humpback whale, *Megaptera novaeangliae* southern right whale, *Eubalaena australis*	dusky dolphin, *Lagenorhynchus obscurus*	Seven	Constantine *et al.* 1998, Visser 1999b, Sorensen 1950
Pinnipeds	-------	-------	None verified	This chapter
Birds		blue penguin, *Eudyptula minor*	One	This chapter

Table 4.2. Foraging Strategies, by Prey Type (see below for definitions of behaviour type)

Behaviour	Ray	Shark	Fin-Fish	Cetacean
Against Wall	✓			
Ambush				✓
Bubble Blow	✓			
Cooperative	✓	✓		✓
Fin Shake	✓	✓		✓
Flipping	✓			
Frisbee	✓			✓
Food Share	✓	✓	✓	✓
Head Butt		✓		✓
Hold Tail	✓	✓		
Longline		✓	✓	
Lunge	✓	✓	✓	✓
Mill	✓	✓	✓	✓
Mud on Rostrum	✓			
Pluck		✓	✓	
Rush	✓			
Shallow Side	✓			
Sediment	✓			
Strand	✓			
Tail Bite				✓
Tail Hit		✓		
Tail Thrash	✓			

Against Wall = used rock face, sea floor or similar substrate to pin prey against

Ambush = used techniques to trap prey unsuspectingly

Bubble Blow = large underwater releases of bubbles

Cooperative = individuals coordinated movements during hunting

Fin Shake = body and dorsal fin shakes as prey is shaken

Flipping = turned prey over to induce tonic immobility

Frisbee = tossed prey across surface, or into air

Food Share = share prey item after it has been caught

Head Butt = hard hit to prey item with head, typically sends prey item out of water

Hold Tail = orca held prey by tail whilst prey was attempting to escape

Longline = removed fish from longline (also see ‘pluck’)

Lunge = fast movement by orca, typically following prey, but may also be on top of prey at surface

Mill = repeatedly dove in varying directions, onto one location (where a location is approximately 5 x 5 m)

Mud on Rostrum = surfaced with mud on rostrum (can extend almost to blow hole)

Pluck = removed prey from line, gently pulled until prey ‘pop’ off the line

Rush = fast following of prey item in very shallow water, less than 3 meters deep

Shallow Side = while pursuing and capturing prey, turned on side to navigate shallow areas

Sediment = foraged on bottom and stirred up sediment

Strand = beached whilst pursuing prey

Tail Bite = bit off tail, debilitating prey

Tail Hit = hit prey, at surface, using tail stock and flukes held perpendicular to surface

Thrash = vertically inverted and vigorously moved tail, subsurface and in air

Although Fertl *et al*. (1996) reported four records of orca foraging on blue sharks (*Prionace glauca*) (including records from New Zealand), detailed descriptions were not provided. The following outlines attacks on three blue sharks. On 9 January 1997 at 0627 hr, five orca were observed off the Kaikoura Peninsula (42° 24' S 173° 45' E). All animals were travelling in synchronous formation (surfacing at the same time) and heading south. At 0657 hr, NZ89 (adult male) surfaced asynchronously and four minutes later all five whales surfaced and began milling (water depth 54 m). Shortly after, a blue shark was seen at the surface. The shark was identified by the blue dorsal surface, overall slender body, and long pointed snout and pectoral fins (Cox and Francis 1997). NZ89 was observed lunging (fast surfacing) in the area where the shark was seen and at 0706 hr, surfaced with a shark in his mouth. He then submerged and together with the others began milling until 0715 hr, when all five orca surfaced synchronously and headed south at approximately six knots. At 0756, NZ89 again surfaced asynchronously and six minutes later either NZ88 (adult male) or NZ89 fast surfaced, chasing another blue shark. NZ88 lunged and bit the shark near the head and submerged with the shark in his mouth, which was not observed again.

In January 1994, whale-watchers video-taped orca (group size not known) off the Kaikoura Peninsula. Just off the 'Sharks Tooth' (42° 25' S 173° 48' E) an unidentified orca was filmed circling a blue shark at the surface. The orca repeatedly fast-surfaced next to the shark. After one surfacing the orca 'high-lifted' its tail in a 'cart-wheel' and using its tail stock and flukes held in a 90° angle from the water, hit the shark hard across the dorsal surface. The orca submerged, and on the next surfacing, hit the shark again in this manner. On the next surfacing the orca took the shark and submerged with the shark in its mouth. Another orca was seen to descend in the same location and the shark was not seen again.

New Zealand orca have also been observed foraging on a mako shark (*Isurus oxyrinchus*), the first record for this species (Visser *et al.* 2000). In this instance, on the 11 November 1998, Bay of

Islands (35° 9.4 S, 174° 11 E), a group of seven orca were observed milling and NZ63 (adult female) surfaced with a shark grasped by the tip of its tail. The shark attempted to escape by swimming vigorously at the surface, but could not. Underwater observations showed NZ63 grasping the shark, this time around its girth. NZ63 released the shark when she approached the author within 4.5 m (see Fig. 1 in Visser *et al.* 2000). The 1.2 - 1.5m shark was identified as a female mako based on the homocercal caudal lobes of the tail, pointed snout, large first and small second dorsal fins, five gill slits, and lack of claspers (Cox and Francis 1997). The shark was bitten again in the girth, tail and in the head by another unidentified orca as NZ63 orca descended with the shark in its mouth. As they descended the shark was consumed (Visser *et al*. 2000).

In addition to the species of elasmobranchs listed above, New Zealand orca have been observed taking school sharks (*Galeorhinus galeus*) off longlines (Visser 2000). This shark species has been targeted by commercial fisheries in New Zealand waters since the early 1900's (Cox and Francis 1997). It is caught mainly by set net and longline (Cox and Francis 1997) and in 1986 quotas were introduced to reduce over-fishing (5,600 tonnes were caught in 1984 alone) (Cox and Francis 1997). Orca have been selectively removing school sharks from lines set to target this species since at least 1984 and typically 5–10 % of the catch is taken (Visser 2000). The school sharks, while still alive and attached to the line, are 'delicately' taken by the tip of the tail, using the teeth at the front of the orca's mouth, and are gently pulled until they 'pop' off the line (Fig. 4.3). This typically occurs at, or very near, the surface. To date, New Zealand orca have only been recorded preying on school sharks when they are attached to longlines (Visser 2000).

Figure 4.3. Orca removing school shark (*Galeorhinus galeus*) from longline by taking the shark by the tip of the tail and pulling until it 'pops' off the line. Photo: Anon.

One other elasmobranch has recently been observed as a prey item for New Zealand orca. On 24 October 1999 and 25 December 1999, different groups of orca (n = 6 and n = 12 respectively) were observed Benthic Foraging for rays. On both occasions the orca were followed as they headed south, parallel to, and approximately 500 meters off sandy beaches in the vicinity of Whangarei Harbour (Ocean Beach, 35° 48' S, 174° 34' E, and Ruakaka Beach, 35° 53' S, 174° 33' E). These beaches extend to the north and south of Whangarei Harbour respectively, which is an area already identified as Benthic Foraging habitat (Visser 1999a). On both occasions, during Benthic Foraging in a depth of 10 - 14 metres, an orca (neither were adult males, but no further details were gathered on their identification) surfaced less than one metre from the research vessel (5.8 m inflatable). They were observed with a ray, held ventral side up, in their mouths, with the tail protruding. The rays were identified as torpedo rays (*Torpedo fairchildi*) by the rounded pectoral fins which form a distinct disc, well separated from the thick rounded tail (Cox and Francis 1997, Thompson 1981). Both torpedo rays were approximately 0.6 m across, wingtip to wingtip. The whales submerged with the prey in their mouths, still held upside down.

Fin-fish

Four species of fin-fish have been taken by New Zealand orca (Table 4.1), (plus two unidentified species). Yellowfin tuna (*Thunnus albacares*) and bluenose grouper (*Hyperoglyphe antarchia*) were both observed being taken off lines (Visser 2000). Two reports from New Zealand recreational fishers confirm that orca also take bait off rod-and-reel lines. In one instance a video suggests an orca took a big-game fishing lure and snapped the line, and in the second instance a live-bait yellowfin tuna of approximately four kg was taken off a big-game line, leaving only the head (Visser 2000).

When taking bluenose, fishers reported losses from orca predation of 5 - 10% per set of line (Visser 2000) and stated that the orca are selective when removing fish, taking only bluenose, and leaving other species. Predation only occured as the gear was hauled up to the surface. The orca did not remove the hooks, but one fisher reported hooks being straightened. Typically, the orca removed the whole fish, but they may also take only the body, severing it just behind the gill-cover and leaving the head attached to the hook. Orca have also been observed eating ‘floaters’ (fish that have distended swimbladders due to fast-hauling from depth, and which consequently come off the hooks and float around the boat) (Visser 2000).

The kahawai (*Arripis trutta*) was positively identified as free-swimming prey in September 1996 off Whangarei Heads (35° 51’S 174° 35’ E). In addition, on two occasions in September 1996 in the Bay of Islands, Northland (35° 14’S 174° 13’ E), an orca was observed to ‘play’ with a porcupine fish (*Allomycterus jaculiferus*) at the surface, but was not observed to eat it. On one occasion a group of three orca were seen to attack and eat a sun-fish (*Mola mola*) at the “Rise”, (34º 10’S 174º 09’ E), approximately 70 km offshore. As the water was clear (visibility was estimated at great than 20 m), surface observations of the attack clearly showed the sun-fish (estimated to be at least 2 m across) killed and consumed by the orca (Visser unpubl. data).

Marine Mammals

No records could be verified which indicate that New Zealand orca eat pinnipeds. Sorensen (1950) states that between 1941 - 45 elephant seals hauled out on Campbell Island with "*shocking wounds which could have been caused by no other agency [than orca]*", however, he did not see any attacks (and it should be noted that great white sharks (*Carcharodon carcharias*) have been recorded off this island and attack pinnipeds). He also stated there was only one sighting of orca off the island during this timeframe. During that sighting the orca were observed attacking a southern right whale (*Eubalaena australis*) but no further details were given (Sorensen 1950). This is the only known record of orca attacking southern right whales in New Zealand, and is not included in Visser (1999b), where interactions of a predatory nature have been recorded between orca and a further six species of cetaceans. In New Zealand waters, the dusky dolphin (*Lagenorhynchus obscurus*) has been recorded for the first time as orca prey (Constantine *et al.* 1998, Visser 1999b), (Table 4.1).

Visser (1999b) records four instances where common dolphins (*Delphinus delphis*) were attacked, but since then there have been two further interactions. The first is represented by circumstantial evidence. On 17 December 1999 at 1130 hr, orca were reported off the Poor Knights Islands (35° 27' S 174° 45' E), Northland, but could not be located by the author. At 1200 hr, a group of approximately 30 common dolphins were found in the same area and one was photographed with fresh bleeding wounds on its side (Fig. 4.4), consistent with those reported by Visser (1999b) and nearly identical to the fresh scars on a Dall's porpoise (*Phocoenoides dalli*), which were attributed to orca (Morejohn 1979). On 25 November 1999, off the Bay of Plenty (37° 25'S 176° 12' E), approximately six orca were encountered during a chase of a group of approximately 200 common dolphins (G. Butler, pers. comm.). Both the dolphins and orca were 'fast-porpoising' with the chase observed for approximately 10 mins. At the end of this time the orca managed to intercept the dolphins and attacked them. No kills were observed, but shortly after the orca and dolphins moved off a juvenile dolphin carcass was recovered, with the tail flukes and tail stock bitten off just anterior to the genital area (G. Butler, pers. comm.). These same orca were then observed attacking a humpback whale (*Megaptera novaeangliae*) (see below).

Figure 4.4. Common dolphin (*Delphinus delphis*) with fresh tooth rake marks attributed to orca (photo I. N. Visser)

Only two published records exists of New Zealand orca attacking humpback whales (Beale 1994, Visser 1999b). Another attack occurred off the Bay of Plenty (37° 26'S 176° 13' E), 25 November 1999, where six orca were seen to attack a single adult humpback whale (G. Butler, pers. comm.). These were the same orca that had been observed approximately one hour earlier, whilst attacking common dolphins (see above). A single orca was observed to breach clear of the water and when the observation vessel was approximately 400 meters from the orca, a humpback whale was identified based on the large pectoral fin which the whale was repeatedly slapping on the water surface. The vessel was shut down and allowed to drift while observations were conducted. The humpback whale moved over to the boat and lay alongside, and was at times close enough to brush up against the boat. During this time the orca were observed to bite the whale and concentrated on the area along the backbone, posterior to the dorsal fin. The orca managed to get on top of the whale during their attempts to bite into its back, but could not maintain this position, and slid off. The humpback was observed to have a small section (approximately 15 cm x 15 cm) of the tail torn away and hanging off the edge of the flukes. There was also a fresh bite on one of the humpback

whale's pectoral fins. The whale was exhibiting laboured breathing and after approximately 30 minutes of observations the vessel had to leave the area. The same area was searched the following day for remains of the humpback whale, but none were recovered (G. Butler, pers. comm.).
No stomach contents have been gathered from stranded New Zealand orca, i.e., the stomachs examined were empty (Visser unpubl. data). However, seven New Zealand orca were taken by a Russian whaling vessel, between 1961 and 1979, and although five had empty stomachs, the remains of "several whale species" (although they do not record which species) were found in the stomachs of a further two orca (Mikhalev *et al.* 1981).

Birds

Only one species of bird has been recorded in the New Zealand orca diet (blue penguin, *Eudyptula minor*). To date, two records exist, one off Cape Brett, Bay of Islands (35° 10' S 174° 20' E) and the other off Kaikoura (42° 24.5' S 173° 45.4' E) (Table 4.1). Although not part of the actual diet of New Zealand orca, the black-backed gull (*Larus dominicanus*), and the red-billed gull (*Larus scopulinus*) have been seen feeding in association with Benthic Foraging orca (Visser, unpubl. data).

Cephalopods and Coelenterates

On two occasions orca have been observed with an octopus in their mouths (Table 4.1). In September 1998, near Home Point (35° 19' S, 174° 22' E), an orca surfaced with an octopus (species unidentified) in its mouth. The octopus was still alive as it's tentacles were moving. The orca submerged with the octopus still in its mouth. In November 1991, at Opitio Bay, Coromandel (36° 42' S, 175° 49' E), an orca (identified as NZ1) was photographed just below the surface, with an octopus in her mouth. (C. Chaldler / M. Glover pers. comm.).

On one occasion, in September 1996, off Whangarei Heads (35° 51'S 174° 35' E), an orca was seen to take a salp (unidentified species) into it's mouth. Although the water was clear, it could not be confirmed if the salp was discarded or consumed (Visser unpubl. data).

Diet of Individuals

Overall, New Zealand orca appear to have a broad diet, however, when looking at specific individuals a breakdown of prey types is possible. Photo-identified and recognised individual orca have been identified eating specific prey item. Of those, most have been seen exclusively eating rays, whereas fewer exclusively eat cetaceans or fin-fish. None have been identified foraging exclusively on sharks (Table 4.3). This table does not included unidentified orca observed foraging and it should be noted that an observation of a prey type does not preclude an individual foraging on another prey type, rather, it reflects the observations to-date.

Table 4.3. Number of orca known to eat prey types
(note, these samples apply only to photo-identified individual orca observed three or more times)

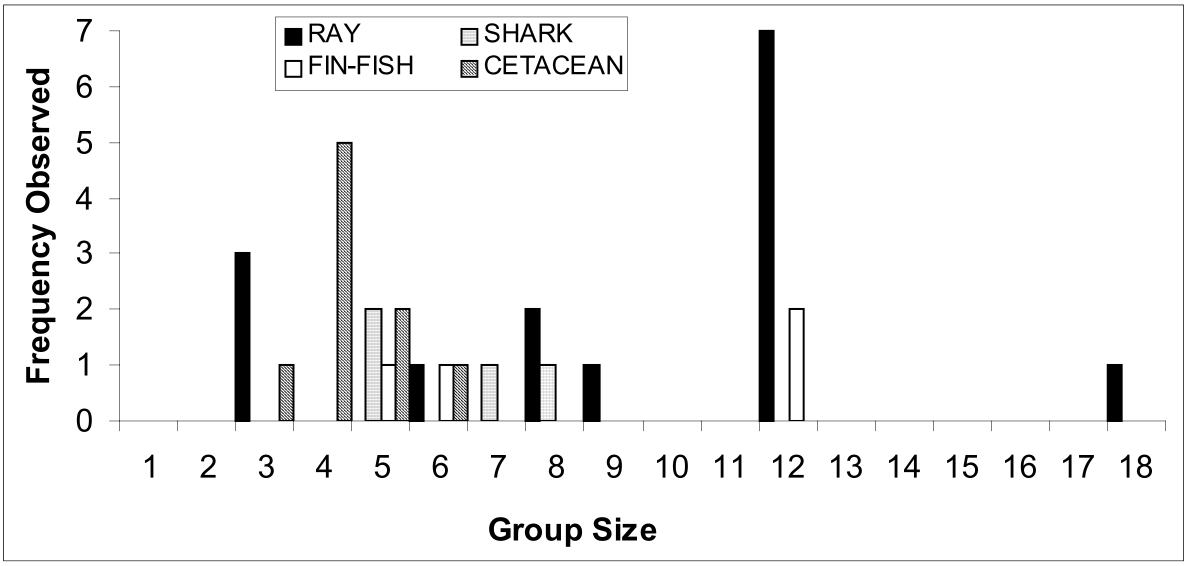
Prey Type	RAYS	SHARKS	CETACEANS	FIN-FISH
RAYS	**43**	**8**	**2**	**6**
SHARKS		**0**	**0**	**0**
CETACEANS			**4**	**0**
FIN-FISH				**5**

(Numbers indicate the number of individual orca known to eat this prey type)

Group Size

Group size varied depending on the food type (Fig 4.8). Although sample sizes are small, it appears that group size during foraging was generally smaller for orca foraging on cetaceans than those foraging on rays. Orca who foraged on rays had the largest range of group sizes (3 – 18 orca), with orca who foraged on cetaceans the smallest groups (3 – 6 orca). There was some overlap of group sizes and prey types (e.g., orca foraging on cetaceans, group size 3 – 6; orca foraging on sharks, group size 5 – 8). The most common group size reported in Visser (1999b), for all types of interactions with other cetaceans in New Zealand waters, was five.

Figure 4.8
Foraging group size, plotted by food type



Predictable Behaviour whilst Foraging

Visser (1999a) described Benthic Foraging for rays (see Benthic Foraging above, Table 4.2 and Visser 1999a for more details of each behaviour). In addition to these details, there is often a sequence of predictable behaviour (see Benthic Foraging above, Table 4.2 and Visser 1999a for more details of each behaviour). Generally, this consists of one orca beginning to mill (presumably upon having 'discovered' a ray) and other(s) travelling to the milling location (on some occasions coming from more than 500m away). The bottom is often stirred up by milling and 'digging' which is usually followed by 'bubble blows' and then capture of the ray. In Auckland Harbour, during one encounter of five hours, two orca (NZ28, adult male and NZ29, SAM) were seen taking 15 rays, where NZ28 caught eight rays and NZ29 caught seven. During this encounter each ray caught was shared between the two animals. When NZ28 was milling (presumably in pursuit of a ray), NZ29 would make short surface dives where his fin was often visible. He would travel small distances during these dives and kept returning to the milling site of NZ28. When a ray was 'located' NZ29 would become 'excited', and swimming inverted, would slap the water with his pectoral fins, tail lob and swim on his back exposing his erect penis (Fig. 4.5). Once NZ28 surfaced with a ray, NZ29 moved in close, usually assuming a head to head position to food share and at this stage both orca were usually observed to 'fin shake'.

Figure 4.5

NZ29 (SAM) showing erect penis during predictable behaviour whilst Benthic Foraging with NZ28 (adult male).

Foraging Strategies and Locations

The four prey types listed above, i.e., ray, shark, fin-fish and cetacean, are all taken by different foraging strategies (a repertoire of foraging behaviours, e.g., see Table 4.2). There are similar behaviours within each prey type and across prey types, however no prey type shares a complete repertoire with another (see explanations of behaviours in Table 4.2). Benthic Foraging for rays contained the most types of foraging behaviours (n = 16) and contained nine unique foraging behaviours (Table 4.2), compared to one each for shark and cetacean foraging, and none for fin-fish foraging. Food sharing, lunging and milling were observed during foraging for all four prey types.

Rays were the most common prey type – determined by number of animals observed foraging in this manner (Table 4.2) and actual number of prey items taken (Visser, 1999, Visser unpubl. data).

The North+South-Island sub-population (see Chapter 2 for definitions of sub-populations) has been observed foraging on all four prey types (Table 4.4). The North-Island-only sub-population has been observed foraging on three of the four (i.e., fin-fish, ray, and shark), whilst the South-Island-only sub-population has been observed foraging exclusively on cetaceans (Table 4.4).

Table 4. 4. Sub-populations observed foraging on prey type

Sub-population	Fin-fish	Ray	Shark	Cetacean
North-Island-only	✓	✓	✓	
North+South	✓	✓	✓	✓
South-Island-only				✓

Foraging Acoustics

Recordings of orca sounds collected during foraging were not analysed, due to low sample sizes. The low sample size was attributed to logistical constraints (e.g., orca moving at speed and the hydrophone could not be deployed, or weather conditions were such that recordings were of limited value, or the orca were too distant for quality recordings). When recordings were possible during foraging events, more than 60% of the times the orca were not vocal, or only echolocation ‘clicks’ were recorded.

Discussion

Ford *et al.* (1998) and Saulitis *et al.* (2000) found strikingly divergent prey preferences in sympatric populations of orca in the PNW. Although two of the proposed New Zealand sub-populations have a diverse range of prey types, there is one sub-population that appears to be limited to one prey type, suggesting this sub-population is not only separated by their distribution but also by foraging eco-type.

Elasmobranchs

Orca predation on elasmobranchs was reviewed by Fertl *et al*. (1996) who noted that elasmobranchs are probably taken more often by orca than has been recorded. Since this review, additional reports of orca interactions with elasmobranchs have become available: an attack on a white shark (Pyle *et al.* 1999) off California USA; an attack on a mako shark (Visser *et al.* 2000) in New Zealand waters; detailed descriptions of Benthic Foraging on rays (Visser 1999a) off New Zealand; and the taking of school sharks from longlines (Visser 2000) off northern New Zealand. The previous maximum number of elasmobranch species taken by an orca population in any one area is three each in the Galápagos Islands, New Guinea and California (Fertl *et al.* 1996). This is in marked contrast to New Zealand, where orca have been observed foraging on eight different species of elasmobranchs (Table 4.1).

Although many New Zealand orca (n = 43) seem to specialise in Benthic Foraging for rays, there does appear to be some risks associated with the technique. Visser (1999a) observed orca stranding whilst foraging for rays in shallow water, and it is likely that, given the location and previous observations of a sub-adult male orca who stranded and was refloated, that foraging for rays contributed to his stranding (Visser and Fertl 2000). An additional risk is that stingrays have barbs in their tail, which they can use in self defence (Cox and Francis 1997, Thompson 1981). A young female orca was found dead off New Zealand in 1998 with stingray (*Dasyatis* sp.) barbs in her lower jaw, neck and spine, which may have become embedded during foraging. These barbs have toxins in them, and it is possible that the female had an allergic reaction to the toxin (Duignan *et al.* 2000).

Norris and Prescott (1961) reported three orca off California in 1958, feeding on an 'electric' ray (*Torpedo californica*), which they shared. This early report is the only previous record of any species from this family as a prey item for orca (Fertl *et al.* 1996). Torpedo or 'electric' rays have a pair of kidney-shaped electric organs (one on each wing) that are used in defence and presumably to stun prey (Cox and Francis 1997, Thompson 1981). The New Zealand endemic torpedo ray is capable of delivering 40 – 50 consecutive shocks and emitting a charge that can induce unconsciousness in a full grown man for approximately one hour (Thompson 1981). It is possible, given that elasmobranchs (including rays) can be induced to exhibit tonic immobility (Henningson 1994), that the orca 'flip' the torpedo rays onto their back to reduce the chances of electrical charges being generated. New Zealand orca have been observed during underwater observations 'flipping' stingrays (Visser, unpubl. data, Fig. 4.6), which again may induce tonic immobility and reduce the ability of the stingrays to defend themselves by using their barbed tail. It is not known if the recent observations of predation on torpedo rays by New Zealand orca are an indication of a shift to less preferred prey items, or if they were captured in an opportunistic manner and are a normal part of the diet for this population.

Visser *et al.* (2000) described a New Zealand orca holding a mako shark by the tail, as has been observed when taking school sharks (Visser 2000) and stingrays (Visser 1999). It is unclear as to why the orca hold sharks by the tail, but possibilities include; 'play', avoidance of bites from the shark, debilitating the shark to prevent escape, allowing young orca to learn to catch sharks, or in the case of the school shark predation, to avoid the longline hooks.

Figure 4.6. Adult male orca (NZ6) with ray held upside-down. The ray is alive, but appears to be paralysed by 'tonic immobility' through 'flipping' (see text for explanation).

Orca killing sharks, by hitting them with their tails, has not previously been recorded, although Similä and Ugarte (1993) observed orca using their tails to kill fish. On all occasions in New Zealand where a shark was killed, with the exception of the longline predation, food sharing or assistance with prey capture was observed. This has also been reported for orca when feeding on stingrays (Visser 1999a, also see Table 4.2). It is likely, given the small size of the school sharks (Fig. 4.7; less than 170 cm, Cox and Francis 1997), that the prey are small enough to be eaten easily by one animal, as has been recorded for orca eating salmon (Ford *et al.* 1998).

Pyle *et al.* (1999) described an attack by an orca on a white shark, a close relative of the mako shark. They commented that the liver was eaten, which is in marked contrast to the livers of the stingrays which are not eaten by New Zealand orca (Visser 1999a). The liver of a basking shark taken off Dunedin (45° 39' S 170° 41' E), South Island, 19 September 1994, was not consumed either (S. Dawson, pers. comm.). As complete consumption of the mako (Visser *et al.* 2000) and blue sharks (this Chapter) were not observed, it could not be determined if the liver was eaten. It is not clear why New Zealand orca do not eat the liver of rays, but as the liver is a filtering organ (Parker 1993), it may bioaccumulate toxins, making the organ itself a risk to consume. Rays have been shown to accumulate silver (Pentreath 1977) and mercury (Horung *et al.* 1993) in the liver. In addition, the livers of sharks and rays have been shown to contain high levels of malonaldehyde (which is capable of inducing mutations) (Filho and Boveris 1993). Further toxicology investigations may show other contaminants accumulated in ray livers.

In investigations of other tissues it has been shown that New Zealand elasmobranchs contain varying levels of heavy metals and organochlorides (Cox and Francis 1997, Fenaughtly *et al.* 1988, Mitchell *et al.* 1982). Sharks, and some rays, are apex predators (Cox and Francis 1997, Devadoss 1978, Strong *et al.* 1990, Taylor and Taylor 1986) and are generally long lived (e.g., up to 55 years for school sharks, Cox and Francis, 1997). Therefore, given that orca are also an apex predator, they may bioaccumulate high levels of heavy metals and organochlorides by foraging on elasmobranchs. These pollutants could reach levels which may pose a threat, as has been found for other populations of orca (e.g., Ross *et al.* 1999, Ross *et al.* 2000, Ross *et al.* 1998). The New Zealand population of orca is small (65 - 167 animals – see Chapter 2), and little is known about the current threats to the population, which may include accumulation of contaminants.

Fin-fish

Ford *et al.* (1998) listed 22 species of fish found in the diet of the PNW orca. However, 13 of these were recorded as prey species only from stomach content analysis (Ford *et al.* 1998). In New Zealand, no stomach contents of orca have been recovered, so the comparatively low number of fin-fish species as prey (n = 4) may reflect the limited sample methods (i.e., field observations only). Similä *et al.* (1996) recorded three species of fish as orca prey in Norway, however one of them, herring (*Clupea harengus*), made up 94% of prey items. Given that the PNW studies have been ongoing since 1973, and only since 1992 in New Zealand, it is likely that as time progresses other species of fin-fish will be recorded as prey items.

Marine Mammals

Bearing in mind that pinnipeds are a primary prey item for a number of populations of orca (Baird 1994, Baird 2000, Ford and Ellis 1999, Ford *et al.* 1998, Guinet 1992, Hoelzel 1991, Saulitis *et al.* 2000, Smith *et al.* 1981), it seems unusual that they have not been verified as a prey item for New Zealand orca (Table 4.1). It is unclear why, as there are reasonable sized populations of pinnipeds on the New Zealand mainland and offshore islands (Bonner 1981, Bradshaw *et al.* 1999, Childerhouse and Gales 1998, King 1983, Walker and Ling 1981). Low numbers of sightings of orca in the New Zealand Sub-Antarctic islands, compared to the other Sub-Antarctic islands around the world such as the Crozet Archipelago, Marion Island and Macquarie Island (Condy *et al.* 1978, Copson 1994, Guinet and Bouvier 1995, Randall and Randall 1990, Rice and Saayman 1987) is possibly linked to the lack of predation on this particular type of prey.

In some areas of the PNW, where the 'transient' type of orca specialises in foraging on marine mammals, foraging on pinnipeds occurred for approximately twice the number of incidences as foraging on small cetaceans (Ford *et al.* 1998). The New Zealand South-Island-only population of orca has been observed swimming past New Zealand fur seals (*Arctocephalus forsteri*), both at haul-outs and in the water. The seals have taken no evasive action, but were aware of the orca's presence as they exhibited low level 'alert' behaviour (e.g., putting their heads underwater to look and low lifting of heads) and observed the orca swim by (Visser unpubl. data). Avoidance behaviour, as well as high level 'alert' behaviour has been recorded for both California sea lions (*Zalophus californianus*) and Steller sea lions (*Eumetopias jubatus*) to the presence of orca known to take pinnipeds (Baird and Stacey 1989). The low level 'alert' behaviour and lack of avoidance behaviour by New Zealand fur seals suggests that they do not consider orca a threat.

Orca foraging on cetaceans has been widely reported from various locations around the world (e.g., Ford and Ellis 1999, Hoyt 1984, Jefferson *et al.* 1991, Matkin and Saulitis 1994, Saulitis *et al.*

2000, Matkin *et al.* 1999), so it is not surprising to find orca preying on them in New Zealand waters. In New Zealand there are no individual orca recorded eating both cetaceans and fin-fish (Table 4.3), which is similar to the dietary division described for the PNW orca where the divergent prey preferences do not overlap between cetaceans and fishes (Ford *et al.* 1998). However, it is interesting to find that some New Zealand individuals feed on both elasmobranchs and cetaceans (Table 4.3). It is unclear why some New Zealand orca may forage on more than one type of prey, but perhaps this diversity in foraging is linked to their flexibility to shift to whatever prey item is opportunistically encountered, a paucity of prey of any one type, or low energetic value of encountered prey types.

Although the South-Island-only population has been observed feeding exclusively on cetaceans, it strongly suggests, but does not preclude, that they hunt only for cetaceans. However, these suggested foraging eco-types may further help to define the sub-populations suggested in Chapter 2 and Chapter 3. As no stomach contents have been gathered from stranded New Zealand orca, it is difficult to ascertain if the field observations and published records (e.g., Visser 1999b) are a direct reflection of the actual diet of cetaceans-only for this sub-population of New Zealand orca. However, where stomach contents have been collected from orca within New Zealand waters (Mikhalev *et al.* 1981), they contained cetaceans. To date, it has not been established which individual orca were involved in any of the larger cetacean attacks reported here, in Visser (1999b) and Sorensen (1950). However, these attacks and those on smaller cetaceans have been recorded from both the North Island and South Island (Visser 1999b, Visser unpubl. data, Table 4.4), suggesting that they could have involved individuals from any of the three sub-populations.

Birds

In other studies (e.g., Ridoux 1987, Williams *et al.* 1990), orca have been reported feeding in association with birds, as has been reported in New Zealand. Birds have been recorded as orca prey items worldwide, although in some instances they are considered more likely to be targeted for 'play' or 'training' (Ford and Ellis 1999, Similä *et al.* 1996). There may be some risk associated with feeding on birds, as van Bree (1961) reported an orca carcass with bird feathers in the trachea and bronchi. Ford *et al.* (1998) found the population of orca in the PNW that specialised in foraging for marine mammals (i.e., 'transients') also took seabirds (five species). In New Zealand, blue penguins have been taken in both the North Island and South Island, however, the identity of the orca was not established, so it can not be ascertained if the orca had also been recorded consuming cetaceans, nor even which sub-population of orca they were from.

Although at least 28 species of birds have been reported in the diet of various populations of orca (Bloch and Lockyer 1988, Condy *et al.* 1978, Similä *et al.* 1996, Stacey *et al.* 1990, Williams *et al.* 1990) only six of the 18 species of penguins have been previously recorded as prey, i.e., king (*Aptenodytes patagonica*) (Condy *et al.* 1978), emperor (*Aptenodytes forsteri*) (Prevost 1961, in Williams *et al.* 1990), rockhopper (*Eudyptes chrysocome*) (Condy *et al.* 1978, Guinet 1992), macaroni (*Eudpytes chrysolophus*) (Williams *et al.* 1990), jackass (*Spheniscus demersus*) (Randall and Randall 1990, Rice and Saayman 1987), and Magellanic penguin (*Spheniscus magellanicus*) (Castello *et al.* 1994), with the blue penguin reported here, the seventh species. It is highly likely, given that seven species of penguin breed on either the mainland or Sub-Antarctic New Zealand islands, and another six species are seen as stragglers in the area (Falla *et al.* 1991), that other species of penguin will be recorded as prey items for New Zealand orca.

Cephalopods and Coelenterates

It was not possible to identify the species of octopuses observed as prey items for New Zealand orca, but given that no octopuses have previously been reported as prey items for orca in the southern hemisphere, they are likely to be a new species. Few reports exist of orca foraging on cephalopods (e.g., Berzin and Vladimirov 1983, Ford *et al.* 1998, Matkin and Saulitis 1994, Nishiwaki and Handa 1958, Rice 1968), yet their close relative, the short-finned pilot whale (*Globicephala macrorhynchus*), typically forages on squid as its main prey item (Seagars and Henderson 1985).

Predictable Behaviour

Hoelzel (1991) reported on two male orca who hunted together in Argentina. One was an adult male when first seen and was estimated to be at least 29 years old, and the other was a sub adult male who matured in 1975. These two males hunted for southern sea lion pups (*Otario flavenscens*), catching and sharing any prey caught. Their behaviour was predictable, just as the behaviour of the two males reported here. Guinet (1992) reported on orca in the Crozet Islands catching elephant seals (*Mirounga leonina*), and other orca coming from several kilometres away to share the prey. Guinet (1992) hypothesised that this allowed the group to adapt to different prey sizes. In other studies of orca, food sharing has been seen for animals that are related (e.g., Hoelzel 1991), and this behaviour has been described in a variety of contexts for the New Zealand orca (e.g., Visser 1999a, Visser 1999b, Chapter 3, this Chapter). Generally, food sharing in New Zealand occurred between animals with higher Association Indices (Chapter 3), suggesting relatedness between those individuals.

Group Size

As outlined in Chapter 3, there is a wide range of group sizes found in New Zealand (2 – 22 orca), with 12 being the most frequently encountered (22%). In Chapter 3 it was suggested that group size is indicative of prey type, i.e., typically, smaller groups would hunt larger prey, and larger groups hunt smaller prey. If group size is linked to prey size, then it could be expected that smaller group sizes would be found for those orca foraging on cetaceans, as has been found for the orca in the PNW (Ford *et al.* 1998, Saulitis *et al.* 2000). Indeed, this is the case in New Zealand, with the most common group size for orca foraging on sharks and cetaceans being five, compared to those orca foraging on rays where the most common group size was 12 (Fig. 4.8). There were ‘outliers’ in group size for orca foraging on rays (group size 3 and 18), but this could be a function of smaller (or larger) groups forming (or splitting) during foraging. Baird and Dill (1996) suggested that larger group sizes, above those expected for maximum energy intake, may be a function of foraging for additional prey types, protection of calves or for other social reasons.

As indicated in Table 4.4, the South-Island-only sub-population has been observed foraging exclusively on cetaceans. It would be expected, therefore, that this sub-population would have small group sizes. The largest South-Island-only group size recorded is four orca (Visser unpubl. data). It could be speculated that foraging for cetaceans requires more cooperation than foraging for rays (although cooperation was observed during foraging for all prey types, Table 4.2), and a smaller group size allows for better coordination and cooperation.

Although a wide range of group sizes has been indicated for orca foraging on fin-fish (5-12), there is only a small sample size (n = 4) and the fish species may vary widely in size. Also, as the taking of fish from longlines is the only method orca have been observed using while taking bluenose, the longline situation creates a ‘false’ environment for the orca to forage in and this may facilitate the development (or not) of groups that might otherwise have formed.

Foraging Strategies and Locations

PNW orca not only specialise in the type of prey they take, but also in the methods and locations they use for hunting (Baird 2000, Ford and Ellis 1999, Morton 1988, Saulitis *et al.* 2000). For instance, ‘transient’ orca use one of two habitats in coastal waters – open water and nearshore (Baird and Dill 1995, Saulitis *et al.* 2000) and ‘transient’ and ‘resident’ orca are typically found in different depth ranges – shallow for ‘transients’ and deeper for ‘residents’ (Baird 2000).

The New Zealand orca have shown differentiation between foraging strategies, with Benthic Foraging for rays the most diverse (16 different foraging behaviours observed, and nine of those unique to Benthic Foraging). Six of those behaviours ('Against Wall', 'Mud on Rostrum', 'Rush', 'Shallow Side', 'Sediment' and 'Strand', Table 4.2) are 'dependent' on the foraging habitat, i.e., these behaviours are intrinsically linked to shallow water where Benthic Foraging typically occurs. For instance, 'Sediment' – where the orca forage on the bottom and stir up sediment, may occur in deep water, but is only visible at the surface in shallow water. 'Shallow Side' is, by definition, occurring in shallow water, where the orca must turn onto its side to navigate and pursue prey in shallow water. Benthic Foraging has not been described for any other population of orca worldwide and may be unique to New Zealand.

Benthic Foraging is typically observed in shallow water - average 12 m; (Visser 1999a, although it may occur in deeper water and not be observed), whereas hunting for dusky dolphins off Kaikoura typically occurs in water over 30 m deep (Visser unpubl. data). In addition, Benthic Foraging typically occurs close into the shore, amongst rocks or in shallow harbours (Visser 1999a), but to date, no attacks on cetaceans in New Zealand waters have been reported from a similar habitat. In general, attacks on cetaceans appear to be conducted in open water habitats (Visser unpubl. data).

Foraging Acoustics

Acoustically the PNW orca have distinct dialects, and typically 'transient' orca are quiet whilst hunting, but become vocal when prey is first caught and during a kill, whereas 'residents' are vocal during much of their hunting (Barrett-Lennard *et al.* 1996, Ford 1989, Ford 1991, Ford and Hubbard-Morton 1990, Matkin *et al.* 1999b, Morton 1988). The New Zealand orca are acoustically 'mixed', with the same individuals at times vocal whilst foraging, and at others quite whilst foraging (Visser, unpubl. data), perhaps reflecting their mixed foraging strategies.

Threats

Slooten and Dawson (1995) identified conservation threats to all species of marine mammals in New Zealand. The issues affecting New Zealand orca include those discussed by Baird (1999) for the PNW populations, i.e., pollutants and the reduction of prey due to human activities. Pollution is discussed in more depth in Chapter 5, however, succinctly it is likely to affect an apex predator such as orca through bioaccumulation of persistent toxic chemicals and contaminants via their prey.

It is likely, given that extensive fishing has occurred for many years around New Zealand waters, that there has been a reduction of potential prey species for New Zealand orca. For instance, school sharks (although only known as a prey item for New Zealand orca when taken off longlines) have been reduced to such low numbers that it was necessary to introduce a quota management system to maintain their economic viability (Cox and Francis 1997). It is not possible to establish if this species was previously taken by New Zealand orca as a free-swimming prey item (i.e., before school shark populations were heavily reduced), but it is likely, given that New Zealand orca have been recorded feeding on three other species of sharks, that school sharks were taken at least occasionally. It is nearly impossible (and beyond the scope of this study) to asses the impact of prey reduction and how that might be affecting the New Zealand orca population. As there appears to be a dietary specialisation within the New Zealand orca population, it may be feasible to investigate each sub-population and its food source separately.

Incidental orca mortality through fishing gear entanglements (n = 6) is relatively uncommon in New Zealand waters (see Chapter 5 for more details) but 'tuna-bombing' and shooting have also been recorded (Visser 2000). Orca have been perceived as a threat to fisheries in many areas around the world and have been shot at and have also been exterminated *en masse* (hundreds were destroyed with machine guns, rockets and depth chargers after a request by fishers off Iceland) (Anon. 1956). A small increase in the perceived threat of these animals to fisheries in New Zealand may result in an increase in efforts to deter them, resulting in increased mortality. Visser (2000) discussed the issues surrounding this aspect of orca/longline interactions (and see Chapter 5), including the suggestion that food is a very positive reward and longline predation by orca will be hard to eliminate when it is constantly reinforced. Considering the small population estimates (Chapter 2), the threats outlined above may be critical to the survival of the New Zealand orca population.

Summary

Worldwide, populations of orca specialise in their foraging strategies and the type of prey they hunt. In New Zealand, there appears to be a similar situation, with some animals specialising in Benthic Foraging for rays, whilst others specialise in hunting for cetaceans (Constantine *et al.* 1998, and Table 4.3 and Table 4.4, Visser 1999b). Those orca who hunt predominantly for one prey type (e.g., the South-Island-only sub-population) could be described as being a 'specialist foraging ecotype'. However, there does appear to be a small group of orca who take a wider range of prey (Table 4.4). Further studies may highlight why, and pinpoint more animals that have a broad diet. Those individuals with a diverse diet (i.e., the North-Island-only and the North+South-Island sub-populations) could be described as 'generalist foraging ecotypes' and perhaps, opportunistic feeders.

In conclusion, given that the New Zealand population of orca appears to be sub-divided geographically into at least three sub-populations, any divisions by foraging eco-types may help to define these sub-populations and assist with management information. The sub-populations may have to be managed separately due to different threats based on their foraging eco-types. For instance, the orca found off the north of the North Island, who forage from longlines, would be more at threat from interactions between fishers than those orca from the South-Island-only population who forage exclusively on cetaceans and may be at threat from bioaccumulation as apex predators. In addition, those orca that forage primarily on rays may be at threat from contaminants through bioaccumulation via run off into shallow harbours, the typical habitat where Benthic Foraging occurs. There may be a need for marine mammal sanctuaries that addresses these issues, for example, protection of shallow harbours and their catchment areas.

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CHAPTER FIVE

Conservation management of orca (*Orcinus orca*) in New Zealand waters

(IMPLICATIONS AND RECOMMENDATIONS)

Executive Summary

The main management issues arising from the findings of this thesis are presented in this executive summary, followed by recommendations. Later in this chapter details are given in more depth and attention is drawn to the relative sources supplying more information pertaining to each issue.

Biodiversity – Where Orca fit in the Big Picture

New Zealand's biodiversity is under serious threat. Orca are an apex predator and would make a useful marine indicator species. Their population is small, suggesting the need for active management. A range of threats are considered and recommended actions given.

Summary recommendations are given in the grey boxes.

- **Incidental kills in fishing gear and Interactions with Fishers**

At least six New Zealand orca have died due to entanglements. New Zealand orca take fish off longlines, at a rate of 5 - 10 %, but overseas up to 100% of the catch is taken. Some fishers in New Zealand shoot orca. The New Zealand Marine Mammal Protection Act (MMPA) gives fishers, engaged in fishing, protection from prosecution.

Reduce mortality due to fishing entanglements, through education of fishers.
Monitor the orca-longline fisheries interactions & net entanglements.
Modify the MMPA to include fishers whilst fishing.

- **Toxic Chemicals**

Orca are long-lived and are in the uppermost marine trophic level. As such they are likely to bioaccumulate toxic chemicals, e.g., dichlorodiphenyl trichloroethane (DDT) and polychlorinated biphenyls (PCB's). Overseas studies have shown orca to have some of the highest levels of contamination of any cetacean. No toxicology studies have been done on New Zealand orca.

Monitor orca as an indicator species, by investigating DDT, PCB's and other toxic chemical levels.

- **Vessel Interactions**

Three orca show scars typical of animals that have been hit by vessels. Two others are presumed to have died after being hit by a boat. The Regulations of the MMPA classify orca as a whale (however they are dolphin). Orca have many behavioural characteristics similar to dolphins, making the vessel interaction aspect of the Regulations difficult to enforce.

Educate boaters, including suggesting the use of propeller guards.
Monitor areas where orca receive high vessel pressure.
Modify the MMPA to allow for behavioural characteristics of orca.

- **Oil Spills**

As New Zealand orca frequent harbours with high vessel usage, and the Whangarei Harbour where an oil refinery is situated, they could be subjected to high risk should an oil spill occur.

Management plans should include the provision for orca in harbours during an oil spill, and prevention of them entering the harbour should an oil spill occur whilst they are outside.

- **Population Size, Distribution, and Structure**

Population size is estimated at 119 (± 24 SE) (December 1996). Three potential sub-populations exist, divided by geographic and possibly social borders. Some individuals may be moving through the area, including from Antarctica. Very little is known about distribution of orca on the west coast of both the North and South Islands.

Continue field effort to maintain database and monitor the population.
Expand survey to the west coast of both Islands.
Strengthen support for the Southern Ocean Sanctuary & Worldwide Whale Sanctuary.

- **Benthic Foraging**

Orca in New Zealand feed on rays by hunting on the sea floor (termed Benthic Foraging), which appears to be unique worldwide. Most Benthic Foraging occurs in shallow harbours. Little is known about the population status or life history of rays in New Zealand waters and current marine reserves do not protect these areas.

Consider establishment of marine reserves in areas where orca benthic forage on rays.
Increase understanding of ray populations.

- **Strandings**

When individual cetaceans strand (as opposed to mass strandings) they are often thought to be sick or dying. In New Zealand, single strandings of orca may be a result of their method of hunting in shallow waters. Eleven orca have been successfully refloated and two of these resighted. One was seen after three years (nine resightings) and the other after four months (10 resightings).

All orca should be refloated, if physically possible.
Photographs should be taken of ALL orca on the beach (including dead animals) for identification.
ALL carcasses should be secured for autopsy, chemical sampling and genetic analysis.

- **Genetics**

New Zealand orca have a high level of malformations. Understanding levels of genetic variability and genetic isolation of likely sub-populations will assist management.

Conduct genetic analysis for sub-populations, when and where resources allow.

New Zealand's Marine Biodiversity

– where orca fit in the big picture

New Zealand's biodiversity is under serious threat and as much as 80% of our indigenous biodiversity is found in the sea (Anon. 1998). To maintain this biodiversity, one method is to manage indicator species, and by default, their habitats. Orca (*Orcinus orca*) are one such species. They are a top marine predator (Jefferson *et al.* 1991, Visser 1999a), with relatively small populations wherever they are found (Baird 2000). Not only is this also the same for the New Zealand population, but in addition, from the evidence gathered during this study (1992 - 1997), it appears that many of the orca seen around the New Zealand coastline are 'New Zealand Orca', not just animals passing by. This may have a significant effect on the way the public views them (Galbraith 1990) and in the way that the Department of Conservation (DoC) handles their management.

In the South Pacific, the paucity of information about orca is reflected in the limited published data. For instance, only a few incidental observations of feeding (e.g., Brown 1988, Gladstone 1988) and one detailed description (Visser 1999b) are reported in the literature. Some papers give minimal details such as sighting reports or strandings, mainly in Australia (e.g., Aitken 1971, Baker 1981, Cotton 1944, Ling 1991, McManus *et al.* 1984). Others present little or no information other than mentioning them as present in the area (e.g., Dahlheim 1981, Mikhalev *et al.* 1981, Perrin 1982).

In New Zealand, Section 28 of the Marine Mammals Protection Act (MMPA) (1978) charges DoC with management and administration of all marine mammals. However DoC lacks information and has insufficient resources to gather the material necessary to manage the orca population of New Zealand. Therefore, the baseline data provided by this research is vital to DoC in order for it to fulfil its obligations under the MMPA, and to make appropriate management decisions. The way the findings presented here are used will be influenced by available funding and priorities.

The IUCN Red Data List of whales, dolphins and porpoises (Klinowska 1991) states world wide, orca are 'Insufficiently Known' as a species to be classified further. However, in all areas where orca have been studied, and a population estimate calculated, the local populations have been demonstrated to be small (some examples are given in Table 5.1).

Table 5.1. Population Estimates of Orca.

Population Location	Estimated number (and year)	Source
Norway	408 (1993)	(Similä and Ugarte 1993)
Crozet Islands	76 (1990)	(Guinet 1991)
Iceland	143 (1988)	(Sigurjonsson *et al.* 1988)
Western Seaboard, North America	Residents; 300 (1993) Offshores; 314 (1993) Transients; 170 (1999)	(Ford *et al.* 1994) (Ford *et al.* 1994) (Ford and Ellis 1999)
New Zealand	119 (± 24 *s.e.*) (1996)	This study

Comparisons between the known characteristics of the orca from Pacific North West seaboard (PNW) (the longest studied populations of orca worldwide) and those found in New Zealand waters are listed in Table 5.2 & 5.3. It should be noted that the paucity of data for the New Zealand population compared to the 'resident' and 'transient' populations in the PNW is directly correlated to the number of studies conducted on the different populations (e.g., graduate degrees; PNW - 15, New Zealand – 1, i.e., this study).

Slooten and Dawson (1995) pointed out four main categories of conservation threats to marine mammals in New Zealand; ① Incidental kill in fishing, ② Entanglement in plastic debris, ③ Other forms of pollution, and ④ The impact of nature tourism. At least two of these are reason for concern for orca, and a third is a strong contender. What these issues, and others, mean in terms of orca management are outlined below.

Conservation Threats

1. Incidental kill in fishing

For many New Zealand marine mammals no data are available on the number of entanglements per year, or whether the impact is sustainable (Slooten and Dawson 1995), and this includes orca. Nevertheless, there have been at least six instances of orca carcasses recovered with distinctive net or rope entanglement marks (Cawthorn 1981, Donoghue 1994, Donoghue 1995, Visser in prep, C. Duffy & R. Parrish pers. comm.), five of which were recorded since this study began in 1992. In addition, on 26 June 1990, off the Bay of Plenty (37° 18’ S, 178° 46’ E), a New Zealand government fisheries observer reported a Japanese tuna longlining boat hooked an orca in the back. The animal subsequently allowed itself to be hauled alongside the vessel, where it was cut free and released alive (S. Baird, pers. comm.). It is highly likely, given that orca carcasses tend to sink (Dahlheim and Matkin 1994), that there were a lot more deaths due to entanglement which went undetected. Given the small population size (119 ± 24 SE, Chapter Two), and the potential for this population to be further divided into at least three sub-populations (Chapter Three), incidental catches of any level may be detrimental to the viability of the New Zealand population.

The International Whaling Commission (IWC) (Anon. 1994) stated that of the forty recognised species of dolphins and porpoises, thirty-one are known to suffer mortality in gillnets. Slooten and Dawson (1995) go on to say that the remaining nine include orca, which are too large to get caught in gillnets, however Donoghue (1994), in a report to the IWC, stated that an orca had been incidentally taken in a gillnet in New Zealand. Fishing by gillnet may not only compete with the orca for their food, but the nets may also be a hazard when the orca manoeuvre in shallow areas (Lien *et al.* 1988). Overseas, orca have been reported drowned in nets (Northridge 1991, Teshima and Ohsumi 1983) and are considered to be susceptible to entanglement in longlines (Sivasubramaniam 1964).

Determining whether the level of incidental kills from nets is acceptable requires adequate information on how many individuals are killed in this manner. Requiring 'no-blame' reportage of all marine mammal fatalities from all fishing methods is a useful start, however there is no requirement for carcasses to be recovered. Requests for complete carcasses, where possible, or skin and blubber samples for genetic and contaminant analysis, teeth for aging, gonads for reproductive status, and stomach contents for diet analysis would assist future management. Education of all fishers (i.e., both commercial and recreational) specifically on the hazards of nets to marine biodiversity, should be increased.

2. Interactions with Fishers

Slooten and Dawson (1995) mentioned a wide range of interactions between fisheries and marine mammals in New Zealand. However, they did not report on the interactions between orca and longlines, where the orca are actively taking fish off the lines, and neither did Baird (1994), who dealt specifically with New Zealand Fisheries Interactions, despite the problem existing in New Zealand waters since at least 1984 (Visser 2000).

To date the species taken from longlines are school sharks (*Galeorhinus galeus*) and bluenose (*Hyperoglyphe antarchia*). In New Zealand, fishers report losses of 5 - 10% (Visser 2000).

However in other fisheries worldwide, longline losses are much higher (see Table 5.2, and Visser (2000) for more details)

Table 5.2. Location of longline fishery, and the amount of catch taken by orca.

Location	Amount of catch taken	Source
New Zealand	5 – 10%	(Visser 2000)
Alaska	20 %	(Northridge 1991)
Bering Sea	92.4%	(Yano and Dahlheim 1995)
Brazil	up to100%	(Rosa 1995)
Indian Ocean	up to 100%	(Sivasubramaniam 1964)

Shooting of orca involved in these longline interactions in New Zealand waters has been recorded on more than one occasion (Visser 2000). As mentioned above, carcasses of orca typically sink (Dahlheim and Matkin 1994), therefore, it is unlikely that animals would be recovered had they been interfered with. In Alaska, initially, regulations under the USA Marine Mammal Protection Act allowed fishers to defend their catch using any means necessary to repel orca (Matkin and Saulitis 1994). Public concern resulted in changes to the Act and it is now illegal in the USA to engage in activities that could cause serious injury or death to cetaceans, including shooting (Matkin and Saulitis 1994). This change in the law has set a precedent for changes in legislation in other parts of the world, where the law allows fishers to protect their catch but where orca may need protection due to their predation from longlines and other fishing methods.

Although Regulation 3 (2) of the New Zealand Marine Mammals Protection (MMP) Regulations (1992) states "*nothing in these regulations applies in respect of any fishing vessel, while the vessel is engaged in commercial fishing*", this regulation was likely instigated to protect fishers from prosecution when accidental and incidental death or injury of a marine mammal occurred (e.g., entanglement or foul-hooking). However, it would seem unlikely that any fisher deliberately causing injury or death to a marine mammal (e.g., shooting with a firearm) would avoid prosecution. Nonetheless, this regulation offers no further definition and thus is open to interpretation, thereby giving fishers the opportunity to interfere with marine mammals that are perceived as competitors. It is recommended that this regulation be further defined and altered, to limit the fisher's protection to only accidental entanglement and foul hooking.

In conjunction with this modification of the Regulations, it would be prudent to monitor the orca longline predation situation, so that if predation increases, measures can be investigated and implemented to prevent the problem from escalating. Food is a very positive reward, and this behaviour will be hard to eliminate when it is constantly reinforced. As Matkin & Saultitus (1994) pointed out, to resolve or reduce the orca-fisheries conflicts, dialogue among fishers, managers and researchers is essential. Fishers are the key to the solution; they are the ones that experience the problem, and have the most to gain from a resolution.

3. Pollution

Toxic, manufactured chemicals, such as dichlorodiphenyl trichloroethane (DDT) and polychlorinated biphenyls (PCB's), are fat soluble organochlorides and are persistent through bioaccumulation. These and other toxic chemicals have been associated with numerous adverse effects in cetaceans, such as abnormalities, tumours and reproductive suppression (Colborn and Smolen 1996, Johnston and McCrea 1992). A number of different species of cetaceans from New Zealand waters have been tested for PCB levels (Jones *et al.* 1994), e.g., Hector's (*Cephalorhynchus hectori*), bottlenose (*Tursiops truncatus*), common (*Delphinus delphis*), and dusky dolphins (*Lagenorhynchus obscurus*), and Minke (*Balaenoptera acutorostrata*), blue (*Balaenoptera musculus*), pygmy right (*Caperea marginata*), Gray's beaked (*Mesoplodon grayi*) and Cuvier's beaked whales (*Ziphius cavirostris*). Jones *et. al* (1994) found PCB levels ranged from low (< 50 ppb) in the baleen whales (e.g., Minke, blue and pygmy right whales), intermediate (100-500 ppb) in open ocean carnivores (beaked whales and common dolphins) and the highest was recorded in the coastal Hector’s dolphin (750 to > 1000 ppb). No orca samples were tested in the Jones *et. al* (1994) study.

It could be speculated, given the long lifespan of orca (50+ years, Bigg 1982), that greater concentrations of toxic chemicals are likely to bioaccumulate in orca than in Hector’s dolphin, which lives for up to 20 years (Slooten 1990). Also, as the trophic level of orca is high and given that New Zealand orca eat dolphins (Visser 1999a) and elasmobranchs (Visser 1999, Fertl *et al.* 1995, Visser 2000, Visser *et al.* 2000 and see Chapter Four), it is likely that this would also contribute to higher levels of PCB’s than those reported for the other New Zealand cetaceans. This is further supported by the observations that some of this predation occurs in harbours adjacent to heavy industry, such as that found in Whangarei and Auckland (Visser 1999b).

Although orca occupy a high trophic level, worldwide very few toxicology studies have been conducted on this species. The few available studies do indicate that toxic chemical levels are relatively high 9e.g., McCutchen 1993, Ross *et al.* 1999, Matkin *et al.* 1999b), and comments such as orca “*are highly contaminated with industrial chemicals, and that the marine mammal-eating transients may be at particular risk for adverse effects*” (Ross *et al.* 1999), and “*biopsy samples indicated elevated and potentially hazardous levels of PCB's and DDT's in their blubber”* (Matkin *et al.* 1999b) are sufficiently clear to portray the severity of the situation. Ford and Ellis (1999) speculated that the population of marine-mammal-eating ‘transient’ orca have contamination levels even greater than those previously recorded for this species and that the levels may be comparable to levels seen in belugas residing in the highly contaminated St Lawrence estuary (Johnston and McCrea 1992). This has proven to be the case with ‘transients’ and also ‘southern residents’ (see

Chapter Two for a description of these populations) who have the highest concentrations of contaminants in cetaceans in the world (Ross *et al.* 2000).

In an Australian study, from over 180 samples from nine species of cetaceans (including three orca), a neonate orca was found to have the highest total DDT in its blubber (28.4 ppm) (Kemper, 1994). Given that mothers off-load a high proportion of their toxic chemical loading onto to their offspring through lactation, and that this animal had not yet had a chance to accumulate its own bio-loading, this is very high value. Although the neonate was not tested for PCB's, it already had more than half of what Wagemann and Muir (1984) considered that the *total* DDT and PCB's concentrations could be (i.e., 50 ppm), before becoming a serious hazard to cetaceans.

Marine mammals are a useful bio-indicator of global pollution by persistent manufactured organics (Tanabe *et al.* 1983) and the higher up their trophic level, the higher the likely accumulated toxins. Any results gained from these animals would reflect the health of the lower trophic levels, making orca a clear choice as an indicator species. However, because reactions to these contaminants can be difficult to monitor (e.g., reactions from immunosuppressant systems), it is difficult to pinpoint exactly what effect they are having on marine mammals and a broad overview of different populations may be necessary. One of the recommendations to come from a conference on the effects of pollution on marine mammals was to encourage long term studies of different populations of cetaceans (O'Shea *et al.* 1999). Future investigations in New Zealand should include analysis of existing blubber samples of orca for PCB's and other toxins, as suggested in the Action Plan for Dolphins, Porpoises and Whales for the Conservation of Biological Diversity (Perrin 1989) and by Slooten and Dawson (1995), who clearly stated that continued collection of data on the contaminant levels in New Zealand cetaceans is recommended. They also suggested that sources of contaminants should be assessed and reduced.

4. Vessel Interactions

The MMP Regulations (1992) within the MMPA (1978) state that DoC is responsible for the enforcement of control of vessel movements around marine mammals. The MMPA classifies orca as a whale, rather than a dolphin, and Part III of the MMP Regulations (Behaviour around Marine Mammals) states that special conditions apply to whales and that "*no vessel shall approach within 50 metres of a whale*." It further states that "*if a whale approaches a vessel the master of the vessel shall, wherever practicable;*

(i) Manoeuvre the vessel so as to keep out of the path of the whale; and

(ii) Maintain a minimum distance of 50 metres from the whale."

Under the MMPA administered by DoC, the first marine mammal watching permit in New Zealand waters was issued in 1987, for the Kaikoura coast. By 1992 (the date this study was instigated), approximately 16 permits had been issued around the country and by mid 1999 the number had increased to 74 in over 26 sites nationally (Constantine 1999). With a further five permits issued by late 1997 in Northland alone (and two more applications submitted), the implications are that the targeting of cetaceans will only increase.

Orca are considered one of the most spectacular of the cetaceans seen on whale watching trips (Duffus and Dearden 1993), and are widely recognised by New Zealander's (Russell 1999, and see Chapter One). Taking this into account and considering the increasing interest in 'whale watching' in the wild (Duffus and Dearden 1993, Hoyt 1992), the potential and expected growth of whale watching in New Zealand waters, and the high number of private boats in New Zealand, it is likely that orca will be subjected to increased pressure from vessels.

In the Bay of Islands there has been an increase in the number of boats looking for and targeting cetaceans (based on the number of boats with marine mammal permits) (Fig. 5.1a). Coinciding with this increase in permits from 1992 to 1994, there was an apparent increase in the number of reports of orca in the Bay of Islands (Fig. 5.1b). However, after 1994, the number of orca sightings has apparently declined, in spite of more boats targeting cetaceans and reporting sightings to the 'Orca Hotline' (see Chapter Two).

Figure 5.1a. Number of boats in the Bay of Islands that have marine mammal permits

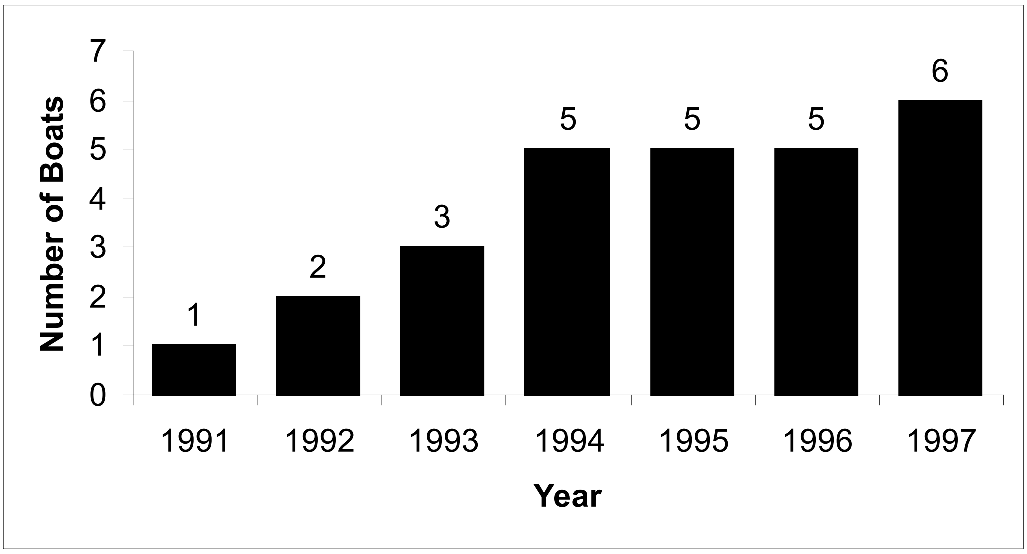
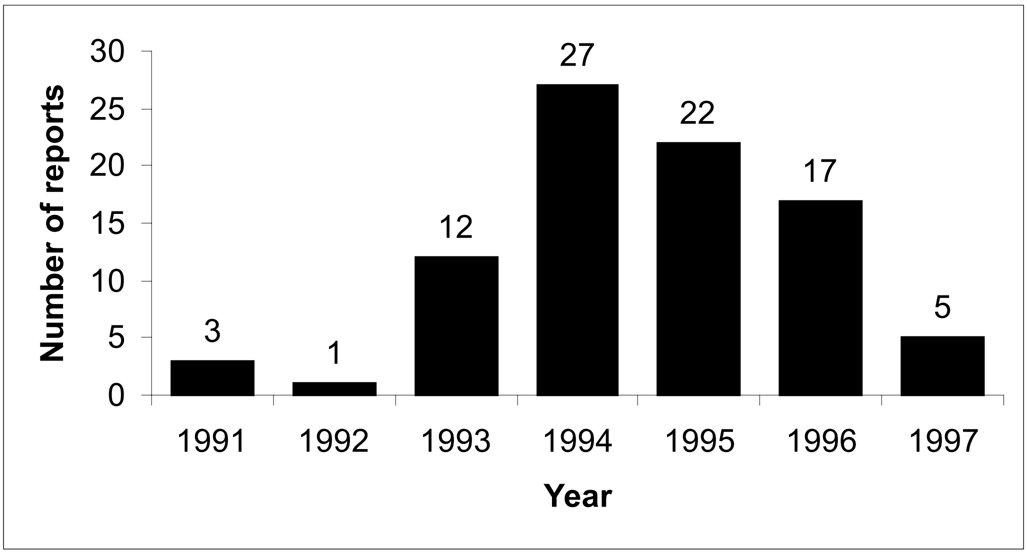


Figure 5.1b. Number of reports of orca in the Bay of Islands



Six orca (5 % of the known population) have been injured as a result of interactions with vessels around the country (Visser 1999c, Visser and Fertl 2000, and Visser unpubl. data). One of these is presumed to have died, one is confirmed dead, one the status is unknown, and the other three have been resighted on a number of occasions (Visser 1999c, Visser 2000). One animal injured by a boat (and the orca who associate with her) appears to have a reduced rate of travel (compared to other non-injured orca), which may be a direct result of her injuries (Visser 1999c).

Orca – Human Interactions

Reports have come in from the public, and through observations of the author, regarding interactions between orca and humans. These interactions have ranged from the orca allowing people to touch them, to an instance where an orca physically mouthed a diver (Anon. 1985) (note that the diver involved stated that the orca was only playing). Other reports (n = 4) have involved divers in similar instances while collecting crayfish (*Jasus edwardsii*). The orca either nudged them on the shoulder or tugged on their dive fin. Worldwide, there have been no verified accounts of orca attacking or killing people in the wild.

In New Zealand most other reports of interactions have involved close encounters with boats. This behaviour has ranged from passes under boats and riding in the wake of boats (Duffy and Brown 1994, Visser unpubl. data) to opening mouths around turning propellers (Visser 1999c). Two reports from different fishermen ‘hosing down’ orca with deck hoses (Visser unpubl. data) suggest that the feeling of bubbles against the skin may attract the orca to the boats. On one occasion, in the Bay of Islands, North Island, an adult male orca (NZ7) was observed by the author to intentionally ‘lift’ a 6 m whale-watching vessel, with eight passengers, partially out of the water.

The behaviour of approaching boats may not have a positive overall effect for the animals, as at least six orca in New Zealand waters have been involved in vessel strikes (Visser 1999c, Visser and

Fertl 2000, and see Vessel Interactions, this Chapter). Worldwide, there have been no verified accounts of orca tipping people out of boats.

One orca, NZ50, consistently made close approaches to the research vessel. This female would lie next to the boat and with her mouth, touch an extended hand (Fig. 5.2). She has a calf who has begun to exhibit the same behaviour (Visser, unpubl. data). Although other species of cetaceans have been noted for their friendly behaviour towards boats and people, e.g., Gray whales (*Eschrichtius robustus*) (Nickerson 1987) and bottlenose dolphins (*Tursiops truncatus*) (Lockyer 1990), those reported from New Zealand waters are the most extensively known for orca.

From a management perspective, it is important that people are educated about this type of behaviour exhibited by New Zealand orca. Chapter One points out that attitudes about orca have generally changed, however, if the public are not informed that orca may make close approaches to divers or boats, they may use inappropriate behaviour, such as shooting an orca with a gun or spear-gun, or starting engines to rush away and thereby injuring the orca. I suggest that measures be taken to educate the boating public, as has been done for the Florida manatee (*Trichechus manatus*) (Swingle and Barco 1999), and suggest the use of propeller guards for small vessels, where appropriate. Furthermore, a modification of the MMP Regulations may be necessary, where orca, due to their behaviour of approaching boats, be excluded from the section that suggests manoeuvring the vessel away from the animals. Although the MMP Regulations (Part III, 18f) requires vessels to take their engines out of gear or to turn them off when viewing marine mammals, this does not often happen. Either of these actions may prevent unnecessary boat activity around the animals and thereby reduce the risk of collisions.

Figure 5.2. Author with NZ50 (Digit). This female orca often approached the research vessel.

Photos by S. Whitehouse.

5. Oil Spills

Slooten and Dawson (1995) pointed out that oil spills can cause major changes to the marine environment. When oil is released into the ocean it initially contains a variety of volatile hydrocarbons, which are the most toxic components of petroleum, and some are known carcinogens (Neff *et al.* 1976). Evaporation of these volatiles from the surface of an oil slick presents a potential threat to cetaceans because these toxic hydrocarbons can be inhaled when animals come to the surface to breath (Matkin and Saulitis 1994).

A number of detrimental effects to cetaceans have been attributed to oil that was either ingested or inhaled, including liver damage (jaundice, necrosis, inflammation, fibrosis), bile duct proliferation, chronic cell infiltrations, stomach ulcerations, renal tubular necrosis and gastrointestinal irritation (Caldwell and Caldwell 1982a, Caldwell and Caldwell 1982b).

Matkin *et al.* (1999b) described how a group of orca in Alaskan waters plummeted in number after the major oil spill created by the grounding of the ship "Exxon Valdez" in 1989. Following the spill, Matkin *et al.* (1994) recorded a mortality rate of 19.4 % in 88/89 and 20.7 % in 89/90 in the 36 member AB pod and these losses were attributed to oil effects. In a population whose normal natural mortality may be closer to 2.2% (Olesiuk *et al.* 1990), this rate would be non-sustainable if applied to the entire population.

New Zealand orca are known to frequent the coastline and harbours (e.g., Auckland Harbour, Whangarei Harbour) and therefore make use of areas of high shipping usage, where oil spills from grounded vessels, or chemicals dumped from bilges such as that which recently occurred at the Poor Knight Islands (Johnson 1999) may be a threat. They also frequent the Whangarei Harbour where an oil refinery is located, making them susceptible to any oil spills that may occur as a direct result of the refinery. Also, New Zealand has a number of oil rigs and personnel have reported orca in their vicinity (Visser unpubl. data).

It is imperative that adequate protocols are in place to protect orca, should an oil spill occur along our coastline. Issues to be considered would include the normal measures for the prevention of an oil spill spreading, such as ‘spill booms’ and foam. In addition, issues such as how to keep the orca away from an oil spill should be addressed. Steps may need to be taken to prevent orca from entering the harbour, such as a barrier across the entrance of the harbour. This could be used until necessary clean-up procedures had been followed.

6. General Conservation Issue and Threats

a). Population Size

One key to making conservation management decisions about any population of animals is a population estimate, as the smaller a population is, the greater the probability of it becoming extinct (Caughley 1994, Hunter 1996). Soulé (1987) described a population (of any species) of less than 500 individuals as small, and the New Zealand orca population fit well within this description (n = 119 ± 24 SE). It is important to know how many animals within the population are viable breeding stock and if they are under threat from any source. These threats can include issues such as stochastic events, but may also include human related threats (Hunter 1996) such as over-fishing, interactions with fisheries, pollution, habitat overlap with humans and attentions from humans (e.g., a wish to control the species, or a wish to observe them). Obviously, large organisms such as orca require more resources than smaller ones and therefore a low population density may evolve (Hunter 1996). This concept is reflected in the low population estimate and widespread distribution of orca around the New Zealand coast (Chapter Two). As the New Zealand orca population is small, it is intrinsically vulnerable to threats, and steps may be required from management to ensure the population is protected.

b). Antarctic Orca

Sightings of orca passing through New Zealand waters, especially if not contributing to the gene pool, may result in an over-estimation of the population size. One such event was a sighting of orca with pigmentation patterns indicative of Antarctic orca stock (Visser 1999d). In terms of management, the issues a sighting like this raises are complex and ecologically interesting. If, as suggested, these orca were from the Antarctic population, then the potential exists for cross breeding of different sub-populations, thereby increasing the size of the total meta-population. However, in other areas, orca from different sub-populations are not thought to mix (Morton 1988) and may in fact act antagonistically toward each other (Ford and Ellis 1999, Shore 1995). Two adult male New Zealand orca have been photo-identified with prolific body scars (albeit superficial) from conspecifics (Visser 1998). However, it could not be ascertained if these scars were a result of aggression (and if from aggression, if they were caused by animals from another sub-population) or some other factor (e.g., given the potential of these animals to inflict much more grievous wounds, these scars must also be viewed in other lights, such as ritualised competitive interactions).

c). Whaling for Orca

Although DoC is responsible for the administration of all marine mammals that are found in New Zealand Fisheries Waters, these may include animals that reside predominantly in other areas such as Antarctica and the Sub-Antarctic waters. Therefore, orca seen passing through New Zealand may come under threat from whaling if they are travelling as far as the whaling grounds found off Antarctica (Mikhalev *et al.* 1981). It has been suggested before that orca from New Zealand waters may migrate to Antarctica, or from Antarctica to New Zealand waters (Kasamatsu and Joyce 1995, Mikhalev *et al.* 1981). However, this present study provided no clear evidence for or against this hypothesis of a true migration. Although Visser (1999d) described orca, possibly from Antarctica, they did not remain in the area and were not resighted in following years (Visser unpubl. data).

Whaling in Area 4 (150° E to 140 ° W, south of the equator), which includes New Zealand, was conducted between 1969 and 1979. Thirty two orca were taken from this area, five of which were from New Zealand waters (Mikhalev *et al.* 1981). Support and strengthening of the Southern Ocean Whale Sanctuary (all waters south of 60° South, which are supposed to be non-whaling areas) (McLay 1994) may help protect sub-populations of orca with large home ranges that include New Zealand and other waters. As an example of the hypocrisy of the New Zealand Government, in regards to the Southern Ocean Sanctuary, whaling ships are permitted to dock in New Zealand for reprovisioning and to take on fuel (Easthorpe 1996).

d). Distribution & Movements

As demographic problems can lead to extinction (Hunter 1996), conservation managers benefit from an understanding of total population size, sex ratios, birth rates and distribution patterns, as well as the likely biases in such information. Such information would help with ongoing management of orca, which is a keystone marine predator (Jefferson *et al.* 1991) and is recognised and appreciated by the public (Hoyt 1992, Russell 1999, and see Chapter One).

Carnivores, such as orca, are at the apex of their food web and they must travel over relatively large areas to obtain food (Hunter 1996). The number of repeat sightings of New Zealand orca, in some cases over 20 times, indicates these animals are highly likely to live permanently or semi-permanently around the New Zealand coastline. The implications of a small population travelling over a large home range could raise issues from a management perspective. For the New Zealand orca population, this behaviour may subject the animals to increased vessel pressure, if they are moving through areas where marine mammal tourism is in operation. Increased chances of habitat overlap with humans and possible detrimental effects associated with this (such as pollution in harbours) may also become an issue. A population that is residing here may be more susceptible to threats such as accumulation of pollutants, as they may be exposed to these threats more often and/or over longer time frames. In addition, a large home range may also subject them to a wider range of interactions with fisheries, which may result in conflicts such as taking of catch and entanglement in fishing gear.

Positive aspects of orca having a large home range may include the increased probability of encountering other individuals to outbreed with (Hunter 1996) and reduced susceptibility to stochastic catastrophes such as oil spills. By not being restricted to a limited home range they may also be more likely to adjust to seasonal and temporal habitat changes.

Nevertheless, although a general pattern of home ranges is known (e.g., orca are more likely to be found in the northern half of the North Island in austral winter months, and in the northern half of the South Island in austral summer months, Chapter Three and Chapter Four) it is apparent that some individuals have not been photo-identified during certain times of the year (Chapter Two). Also, there are periods throughout the year when orca sightings are not prevalent (Chapter Two) and long periods when individuals are not sighted (Chapter Two and Chapter Three). To better understand the processes that govern these animals, it is vital to understand where they are going.

This study had unequal sampling throughout New Zealand, and further information on orca off the west coast of both islands is needed. Furthermore, as has been shown in Chapter Two, individuals can travel up to 169 km per day, and using this distance/day as an example, it would take an orca approximately 13 days to reach Australia, and (from Stewart Island) approximately 25 days to reach the general Ross Sea, Antarctica area. One study in California (Goley and Straley 1994) identified orca previously sighted in Alaskan waters, 2660 km away and 32 months later. This is well within the distances travelled by New Zealand orca (Visser 1999, Chapter Two). It is also feasible that orca are travelling from other areas into New Zealand waters (Visser 1999d). If New Zealand orca are travelling greater distances than already recorded, it may take a while before, if ever, any matches are made between here and the outer limits of their home range. In Australian waters, as yet, no photo-identification studies on orca are being conducted. Should photo-id studies begin in any areas adjacent to New Zealand it would be prudent to exchange information and catalogues.

e). Benthic Foraging – a unique culture

Orca in other parts of the world may follow seasonal movement of their food source (e.g., Felleman *et al.* 1991, Similä *et al.* 1996). There is very little, if anything, known about the movements of ray species found in New Zealand waters. This lack of data adds to the uncertainty of maintenance and management of the orca population. Although there appears to be some seasonal movements by one potential sub-population between the North and South Islands (Chapter Two), it is not known why the orca show these temporal distributions. It is also likely, given the nature of Benthic Foraging and the habitat that it occurs in, that it may be prevalent in other harbours around the country (Visser 1999b).

The separate foraging strategies (e.g., Benthic Foraging, *vs* Marine Mammal Predation, Chapter Four) seen in the New Zealand orca populations may be learned through cultural transmission, as has been suggested for orca in the PNW (Heimlich-Boran 1988). By definition, 'culture' is "*inherited ideas.….and knowledge….which are transmitted and reinforced by members of the group*" (Hanks 1986). As illustrated in Chapter Three, the associations between those animals that food share, and therefore forage in similar ways, is higher than for those that do not food share. As orca in other populations have been shown to maintain tight social groups (Ford *et al.* 1994), it is assumed that they would be passing on 'traditions' such as foraging techniques. In other studies, orca show location-specific behaviour (Heimlich-Boran 1988) and this may assist in delineating separate foraging populations in New Zealand waters. From a management perspective, if there are different orca sub-populations, and each has distinctive foraging strategies, this further reinforces the importance of separate management policies for each sub-population.

Thirty percent of New Zealand's land has been reserved for biodiversity (Anon. 1998), but marine reserves are few (only 0.1 % of the territorial seas around the main islands of New Zealand are fully protected) (Parliamentary Commissioner for the Environment 1999). Moreover, these include no areas such as inner harbour waters where orca feed on stingrays. Consideration of reserving greater marine areas, including harbours, would potentially assist orca and a wide range of other marine biodiversity. Research on population sizes and ecology of rays could also assist in the management of New Zealand orca populations.

f). Strandings & Rescues – worth the effort

The debate of the effectiveness of refloating stranded cetaceans is fuelled more by failures (Geraci and Lounsbury 1993, Odell *et al.* 1989) than successes (Visser and Fertl 2000). The key to knowing if a rescue was successful is a resighting of the previously beached animal. Generally, the methods advocated to achieve a resighting involve tagging the animal before release (Odell *et al.* 1989). In New Zealand, refloated cetaceans have not been tagged, with the exception of cotton tape tied around their tail stocks (S. Whitehouse, pers. comm.). The relatively non-invasive method of photo-identification (Bigg 1982) has additionally been used on some individuals (Visser and Fertl 2000, Visser unpubl. data).

It is commonly thought that cetaceans who strand as individuals do so because they are injured, sick or dying (Geraci and Lounsbury 1993), however, in some cases this may be a misconception, as in New Zealand single orca strandings have been observed occurring as a result of foraging strategies, i.e., hunting for stingrays in shallow waters (Visser 1999b), and may not be linked to ill health (Visser in prep). Since collection of records began in 1880 (Hector, 1880, Visser and Fertl 2000), 43 events have occurred involving at least 84 killer whales. Between 1980 and 1988 these events have occurred at least every two years, and subsequently every year (Visser in prep). Twenty-four live strandings occurred, involving 63 killer whales, of which 17 animals were successfully refloated and two of these have been resighted on numerous occasions; one, after a three year period (resightings, $n = 9$) (Chapter 2), and the other after four months (resightings, $n = 11$) (Visser and Fertl 2000). Both of these orca stranded as single animals. The significance of these results is high, when the small population size is taken into account.

These results should be heeded when the fates of stranded orca are being considered. It is of vital importance that systematic photographs and measurements (and benign samples, e.g., 'skin-scrapes') of stranded orca are taken before their release. Only four orca have been photo-identified on the beach at a stranding, and two of these have been re-identified at sea. It is highly likely, given this resighting rate, that further rescues will produce similar results. It is also important that every effort is made to secure *all* orca carcasses, and not leave them to drift away on the tide. Due to the nature of orca carcasses sinking, the recovery of each one is of incredible scientific value. In cases where mass strandings occur, *all* carcasses should be secured, to allow necropsies and samples to be compared between individuals (e.g., relatedness, comparative aging, PCB loadings between mothers and offspring (see above), toxic chemical contamination, diet, etc.)

g). Genetics

According to the small population paradigm (Caughley 1994), small population size can increase the likelihood of gene loss through mechanisms such as gene drift and inbreeding. The New Zealand orca population is small and appears sub-divided into at least three sub-populations. At least two of these sup-populations apparently do not interact and the extent of gene flow between the others is unknown. Reduced genetic variability can lead to problems such as decreased survival rates, low fertility rates and deformities (Hunter 1996). Deformity rates are fairly high in the New Zealand population of orca. Twenty three percent of the adult male population of New Zealand orca have collapsed, collapsing or bent dorsal fins (Visser 1998). No causative factors have been determined, but it must be remembered that other contributing components such as pollutants and exposure to certain unidentified environmental conditions (e.g., poor nutrition) should also be taken into consideration. Nonetheless, these results are significantly higher than in other populations where collapsed and bent fins are found, e.g., 6.5% (British Columbia, J. Ford, pers. comm.), 0.01% (Alaska, C. Matkin, pers. comm.) and 0.57% (Norway, T. Similä, pers. comm.) of the adult male population. A further two New Zealand orca (females) have been recorded with vertebral column malformations (Berghan and Visser 2000) and one female has been photographed with an 'under-shot' jaw (Visser unpubl. data). If the high frequency of deformities seen in New Zealand orca do relate to a small gene-pool, it is important that further reductions of population size do not occur.

In wild populations, even if inbreeding occurs, genetic problems may not manifest themselves. For instance, the Indian rhinoceros appears to have retained a high level of genetic diversity, even though the population is small. This may be a result of high mobility of some individuals and long generation times (Dinerstein and McCracken 1990), as is seen in orca. Moreover, for some species, inbreeding is a normal mating behaviour (Craig 1994) and may help to guard against 'outbreeding depression' where mating can occur between individuals that are too genetically dissimilar (Hunter 1996).

Although orca are found world wide (Heyning and Dahlheim 1988), distinct groups have been found to be genetically isolated (Hoelzel and Dover 1991, Matkin *et al.* 1999b). Therefore, it may be prudent to consider the New Zealand population of orca as a separate and isolated population - perhaps made up of semi-isolated sub-populations. Investigations of genetic variability and levels of genetic distinctiveness of the New Zealand sub-population and those from adjacent areas, such as Australian waters and the Ross Sea, Antarctica should be instigated. Where possible, samples from live animals should be humanely collected (e.g., 'scrub' or 'skin-scrape' samples) for genetic analysis.

Education

The IUCN Red Data List on Whales, Dolphins and Porpoises, recommends that appropriate education must form an integral part of any conservation strategy for this species (Klinowska 1991). The issues outlined above also highlight the need for education, in particular in areas such as entanglement, pollution, vessel interactions and orca behaviour. Although the New Zealand public can clearly identify the species and are aware of its intrinsic value, they may not be aware of its unique status as a 'New Zealand' population of orca, its potential behaviour (e.g., unique foraging strategies, or close approaches to humans), value as an indicator species, or value in terms of biodiversity.

Monitoring

Differences within a species can be of strategic value to conservation because they provide a clear justification for protecting a species across its entire geographic range, including all subspecies and populations (Hunter 1996). Although it appears that orca are found in relatively small populations worldwide, this would be expected for any top predator. It may be shown, as more orca populations are studied, that they are all vulnerable. In New Zealand, effective management of the orca population needs to include strategies that incorporate continued selective monitoring of population estimates and behavioural observations. The best management policy to do this may be to monitor key locations, such as Region One and Region Four (for detailed descriptions of these areas see Chapter 2). Monitoring may, due to resources, have to be conducted on a scheduled basis, perhaps every five years, and be restricted to critical aspects, such as photo-identification, behavioural observations, toxic chemical analysis and genetic analysis of the proposed sub-populations. The management of this population warrants a precautionary approach at the very least. Continuing to do nothing is not an option if New Zealand is to live up to its responsibilities under the International Biodiversity Convention (Anon. 1998).

Recommended Change to Status

The Hector's dolphin, New Zealands' only endemic cetacean, has been researched long-term (Dawson and Slooten 1987, Slooten and Dawson 1994). This research has shown that the population is small - estimated to be between 3000 - 4000 individuals (Slooten and Dawson 1988), leading to it being classified by the IUCN as 'Vulnerable', but the research has also led to the declaration of a Marine Mammal Sanctuary at Banks Peninsula where the use of gillnets, the species largest threat, is severely restricted (Dawson and Slooten 1993).

Baird (1999), in reference to a small population of orca in British Columbia/Washington, made the astute comment that without a 'Threatened' classification, it seems unlikely that anything will be done regarding mitigation of the impacts that are probable threats to the population. Reclassification of the New Zealand population of orca from the erroneous category of 'common' (Taylor and Smith 1997), to 'Threatened' or 'Rare' would hopefully see more effort put into their management, as has occurred for Hector's dolphins. Although 'red listing' the population does not in itself confer protection, it does impose moral pressure on the New Zealand Governments to act accordingly.

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