ENDANGERED SPECIES ACT
DRAFT STATUS REVIEW REPORT
for
Hector's Dolphin
(***Cephalorhynchus hectori***)

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NATIONAL MARINE FISHERIES SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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DISCLAIMER

This document is a compilation of the best available scientific and commercial data and a description of threats to Hector's dolphins (*Cephalorhynchus hectori*). This document is currently undergoing public review and should not be viewed as a final product. This document also does not represent a final decision by the National Marine Fisheries Service (NMFS) on whether this taxon or any subset thereof should be listed as threatened or endangered under the Endangered Species Act of 1973 (ESA). Prior to making a final decision with respect to listing Hector's dolphins under the ESA, NMFS will consider information in this document; public comments; other relevant biological and threat information that may become available; efforts being made to protect the species; and all relevant laws, regulations, and policies. The result of that decision will be posted on the NMFS web site (www.nmfs.noaa.gov/pr/) and announced in the *Federal Register*.

Contents

Executive Summary

This draft report was produced in response to a petition received from WildEarth Guardians on July 15, 2013, to list 81 marine species or populations as endangered or threatened under the Endangered Species Act (ESA). Five of the petitioned species or populations were marine mammals. The National Marine Fisheries Service (NMFS) evaluated the petition to determine whether the petitioner provided substantial information as required by the ESA to list these marine mammals. On February 21, 2014, NMFS announced in the *Federal Register* that the petition did present substantial information that listing may be warranted for Hector's dolphin (*Cephalorhynchus hectori)*; and NMFS requested information on this species from the public (79 FR 9880). Subsequently, NMFS initiated a status review of this species, which is documented in this report. This draft report summarizes available data and information on Hector's dolphins and presents an evaluation of the status and extinction risk of its component subspecies, the Maui's dolphin (*C. hectori maui*) and the South Island Hector's dolphin (*C. hectori hectori*).

The Hector's dolphin is one of the world's smallest dolphins and occurs only in the coastal waters of New Zealand. Substantial declines in this species have been detected for most populations, mainly as a result of bycatch in gillnets. The North Island subspecies, Maui's dolphin, is estimated to only include about 55 dolphins over one-year of age (95% CI: 48 – 69, (Hamner *et al*. 2014b)), and present abundance of the South Island (SI) Hector's dolphin is about 11,923 to 18,492 dolphins. The largest threat to both subspecies has been identified as bycatch in commercial and recreational gillnets and trawls. Other habitat-related threats, disease, and tourism are also thought to be contributing to varying degrees to the extinction risk of both subspecies. Fisheries restrictions and other management efforts have gradually increased; however, both subspecies are still expected to decline as a result of bycatch. The Maui's dolphin also faces serious demographic risks due to low abundance, a low population growth rate, a restricted range, and low genetic diversity. The relatively more abundant and more widely distributed SI Hector's dolphin faces less imminent risk but is still expected to slowly decline due to continued bycatch and other threats, in particular disease and impacts associated with tourism. This subspecies exists as three genetically fragmented populations that are thought to have restricted connectivity and relatively low genetic diversity. Overall, we find that the Maui's dolphin has a very high risk of extinction and that the SI Hector's dolphin is facing a moderate risk of extinction.

1.0 INTRODUCTION

1.1 Scope and Intent of the Status Review

On July 15, 2013, NOAA's National Marine Fisheries Service (NMFS) received a petition from WildEarth Guardians to list 81 marine species or populations as endangered or threatened species under the Endangered Species Act (ESA). If a petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, NMFS is required to promptly commence a status review for the particular species to help determine whether the petitioned action is warranted (16 U.S.C. §1533(b)(3)(A)). NMFS determined that the petition had sufficient merit for further consideration, and status reviews were initiated for 27 of the 81 species or populations, including Hector's dolphin (see http://www.nmfs.noaa.gov/pr/species/petition81.htm). This report documents the status review for Hector's dolphin (*Cephalorhynchus hectori*).

This document is the scientific review of the biology, status, and future outlook for *Cephalorhynchus hectori* based on the best available data and information. This status review also includes an analysis of threats to the species and makes conclusions regarding the extinction risk of the species. The intention of this status review report is to provide a thorough and accurate review and analysis of the available information to inform a subsequent determination about whether this species warrants protection under the ESA.

Information presented in this draft report is subject to revision in response to public comments as well as to any new data that become available prior to NMFS making a final decision on the petitioned request. Public comments, data, and information were reviewed through June 23, 2016, in preparing this draft report.

Throughout this report, we will refer to the species, *C. hectori*, by the common name, Hector's dolphin. Although the South Island subspecies, *C. hectori hectori*, retains the species' common name, we will refer to it as the South Island (SI) Hector's dolphin to avoid confusion between the subspecies and species. Throughout this report we will refer to the North Island subspecies, *C. hectori maui*, by its common name, Maui's dolphin. As was done in our 90-day finding and as supported by subsequent comments from the petitioner, WildEarth Guardians, this status review addresses both subspecies.

2.0 SPECIES DESCRIPTION

2.1 Taxonomy and External Characteristics

Cephalorhynchus hectori (van Beneden, 1881) is a dolphin within family Delphinidae and one of four recognized species within its genus. The *Cephalorhynchus* genus may have originated from a common Lissodelphinine ancestor in South Africa; and its four member species, which are among the smallest dolphins in the world, occur only in the Southern Hemisphere (Dawson 2009). Mitochondrial DNA (mtDNA) studies support the monophyly of *Cephalorhynchus* and its rapid divergence from the other genera in the Lissodelphininae subfamily (Pichler *et al.* 2001). The basal species is Heaviside's dolphin (*C. heavisidii*), followed by Hector's dolphin, and then two South American species, the black (Chilean) dolphin (*C. eutropia*) and Commerson's dolphin (*C. commersonii*; Pichler *et al.* 2001).

Two subspecies of Hector's dolphins, *C. hectori hectori*, the SI Hector's dolphin, and *C. hectori maui*, Maui's dolphin, have been formally recognized on the basis of multiple morphological distinctions and genetic evidence of reproductive isolation (Baker *et al.* 2002; Pichler 2002, Hamner *et al.* 2012a). Maui's dolphin may have evolved as a consequence of its extreme site fidelity and a population bottleneck (Dawson 2009). In 1946, the subspecies *C. hectori bicolor* was proposed but later invalidated (Van Bree 1972).

Hector's dolphins have short and stocky bodies, no external beak, and a relatively large fluke (Slooten and Dawson 1988). There are 26 - 32 pairs of small, conical teeth (1.7 – 2.2 mm diameter) in the upper and lower jaws (Baker 1978). Mature adults of both subspecies typically have a total body length of 119-145 cm (Slooten and Dawson 1994). Maui's dolphins are larger than the SI Hector's dolphins, and adult females of both subspecies reach larger sizes than the adult males. Maximum total body length (TL) for SI Hector's dolphins reaches at least 144 cm for males and 153 cm for females. Maximum total body length for Maui's dolphins reaches at least 146 cm for males and 163 cm for females (Baker *et al.* 2002).

An external characteristic that distinguishes Hector's dolphin and is unique to the genus *Cephalorhynchus,* is the rounded dorsal fin, which has a shallowly sloping anterior edge and a convex posterior edge (Dawson 2009). Variability in nicks or cuts in the dorsal fin and coloration markings among individual dolphins has allowed for identification and development of photo-identification catalogues for portions of some study populations (Slooten and Dawson 1988, Rayment et al. 2009a; Gormley et al. 2012); however, only about 10-16% of the dolphins have sufficient distinctive markings to allow for individual identification (Pichler 2002, Slooten et al. 1992, Rodda 2014). Other notable external features of Hector's dolphins are the rounded or

paddle-like pectoral fins, typically with a serrated leading edge (Slooten and Dawson 1988), and a blowhole that is located slightly left of center (Slooten and Dawson 1988).

Hector's dolphins also have distinctive and complex color patterns. The sides of the head, tail, dorsal fin, and flippers are black (Baker 1978). The tip of the jaw is dark, and the throat, lower jaw, and belly are white (Leatherwood *et al.* 1983). A thin black line curves over the head to just behind the blowhole (Leatherwood *et al.* 1983). Anterior to this line, the forehead is grey and much of the rest of the body is also grey (Leatherwood *et al.* 1983). Sexual dimorphism in the coloration pattern around the genital area has been described (e.g., Slooten and Dawson 1988, Slooten and Dawson 1994). Typically, the genital slit in males is surrounded by a large dark grey patch, whereas females have a very small grey mark along the genital slit or a plain white belly (Slooten 1988a). Baker *et al.* (2002) noted variation in color patterns among males, including two dead males that had very small or no genital patch. Newborn calves share the same general color pattern as adults but are darker and have a somewhat yellow tinge to the white areas (Slooten and Dawson 1994). Calves also have 4-6 pale bands on their sides between the flippers and the anus. By about 6 months of age, these bands disappear and the coloration lightens to the adult form (Slooten and Dawson 1994). Color is known to change after death, complicating the ability of researchers to document and understand variations in color patterns.

2.2. Range, Distribution, and Habitat

Hector's dolphin is a coastal species endemic to New Zealand. Historically, Hector's dolphins are thought to have ranged along almost the entire coastlines of both the North and South Islands of New Zealand (Cawthorn 1988, Russell 1999, Pichler 2002, MFish and DOC 2007a). The two subspecies probably became initially separated by the opening of Cook Strait during the late Pleistocene and Holocene interglacial periods, and this isolation was likely maintained through behavioral mechanisms such as natal philopatry and small home ranges (Pichler 2002, Baker *et al.*, 2002, Dawson 2009). Currently, Maui's dolphins occur along the northwest coast of the North Island, between Maunganui Bluff in the north and Whanganui in the south (Currey *et al*. 2012; Figures 2a and 2b). Occasional sightings and strandings have also been reported from areas farther south along the west coast as well as in other areas such as Hawke Bay on the east coast of the North Island (Baker 1978, Russell 1999, Ferreira and Roberts 2003, Slooten *et al.* 2005, MFish and DOC 2007a, Du Fresne 2010).
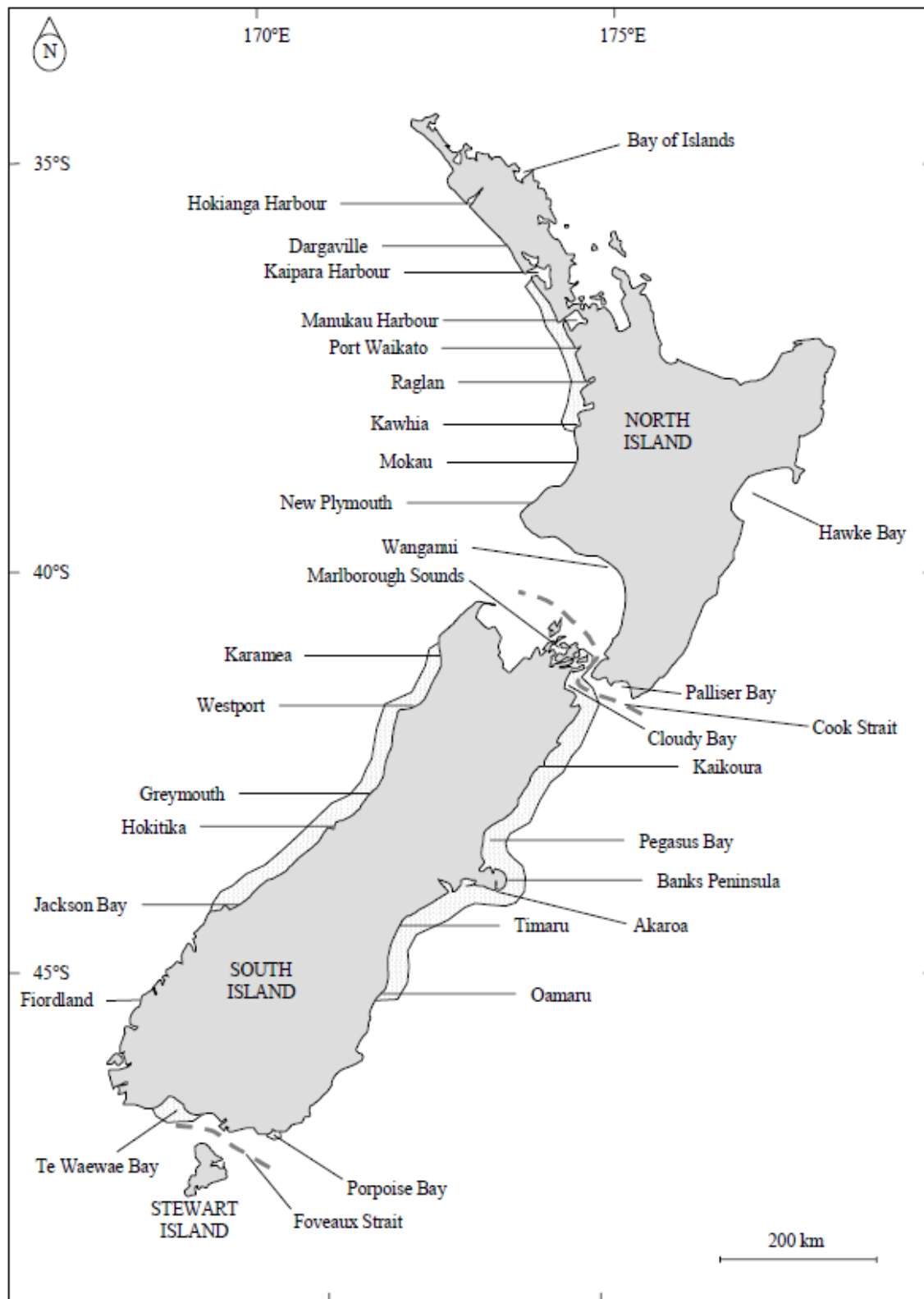
Figure 1. Generalized distributions (shaded coastlines) of four regional populations of Hector's dolphins with geographic points of reference for the North and South Islands of New Zealand. (Taken from Pichler 2002.)

The SI Hector's dolphin currently has a fragmented distribution around the South Island (Figure 2c; Dawson *et al.* 2004, Rayment *et al.* 2011b) and consists of at least three, genetically distinct, regional populations (Pichler 2001, Pichler 2002, Hamner *et al*. 2012a). SI Hector's dolphins are most abundant around Banks Peninsula, Cloudy Bay, and Cliffords Bay on the east coast, and along the central west coast of the South Island (Figures 1 and 2c). Distinct and localized populations also occur on the south coast in Te Wæwæ Bay, Toetoe Bay, and Porpoise Bay (Dawson and Slooten 1988b, Clement *et al*. 2011, Hamner *et al*. 2012a, Rodda 2014, Mackenzie and Clement 2014). The connectivity between these regional populations, especially the south coast populations, appears to be limited (Bejder and Dawson 2001, Hamner *et al*. 2012a). Hector's dolphins do not appear to occur offshore of or within the deep water fiords of Fiordland, although they have been sighted there on rare occasions (Dawson and Slooten 1988b, MFish and DOC 2007a).

Hector's dolphins are typically sighted within about 20 nautical miles (nmi; 37.0 km) of the shore and in water less than 100 m deep (Slooten *et al*. 2005a, Rayment *et al*. 2011b, Mackenzie and Clement 2016). Based on small boat transect surveys that extended 5 nmi (9.26 km) off Banks Peninsula in summer 1985/86, Dawson and Slooten (1988b) reported that 45.5% of the 90 SI Hector's dolphins observed were found within 0.43 nmi (800 m) of the coast and that these results were consistent with their observations from offshore surveys from other locations around the South Island. Similarly, in 2003, in aerial surveys that extended 15 nmi (27.78 km) offshore of the west coast of the South Island, Rayment *et al*. (2011b), found that the highest sighting rate (i.e., number of dolphins/ nmi) occurred within 1 nmi (1.85 km) of shore and declined to zero by 6 nmi from shore. In this study, no observations of SI Hector's dolphins occurred beyond this distance from shore or in water deeper than 60 m despite extensive effort (Rayment *et al*. 2011b). More recent aerial surveys along the west coast of the South Island have extended even farther offshore - out to 20 nmi (37.0 km) and demonstrate that SI Hector's dolphins can range at least 20 nmi (37.0 km) from shore and occasionally in waters as deep as 200 m (Mackenzie and Clement 2016).

For the North Island, an extensive review by Du Fresne (2010) of both published scientific surveys and unpublished opportunistic sightings data indicated that Maui's dolphins are most frequently found within 4 nmi (7.4 km) of the coast but do occasionally occur at least as far as 7 nmi (13 km) offshore. Sightings data included in Du Fresne's (2010) review as well as reported opportunistic sightings of Maui's dolphins are available from DOC's database (e.g., Figure 2a, http://www.doc.govt.nz/our-work/our-work-with-maui-dolphin/maui-dolphin-sightings/).
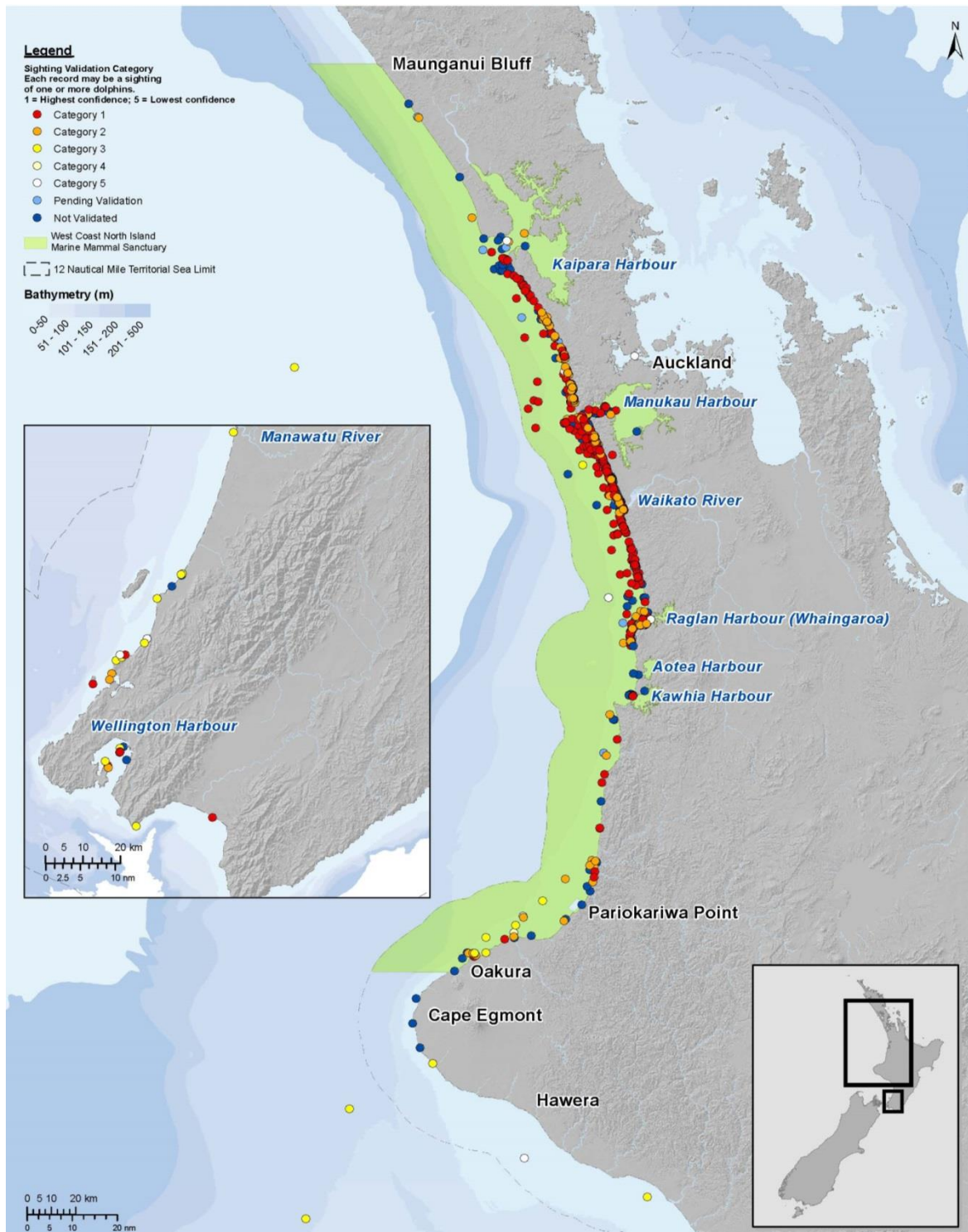
Figure 2a. Distribution relative to shore and water depth of Maui's dolphin sightings reported from 2002 to April 19, 2016, to the DOC sightings database. The plot includes all data, regardless of level of validation (categories 1-5, with 5 being least reliable). The green zone represents the Marine Mammal Sanctuary, which extends 12 nmi offshore. Source: NZ Department of Conservation. See http://www.doc.govt.nz/our-work/our-work-with-maui-dolphin/maui-dolphin-sightings/ for more information about these data and additional plots.
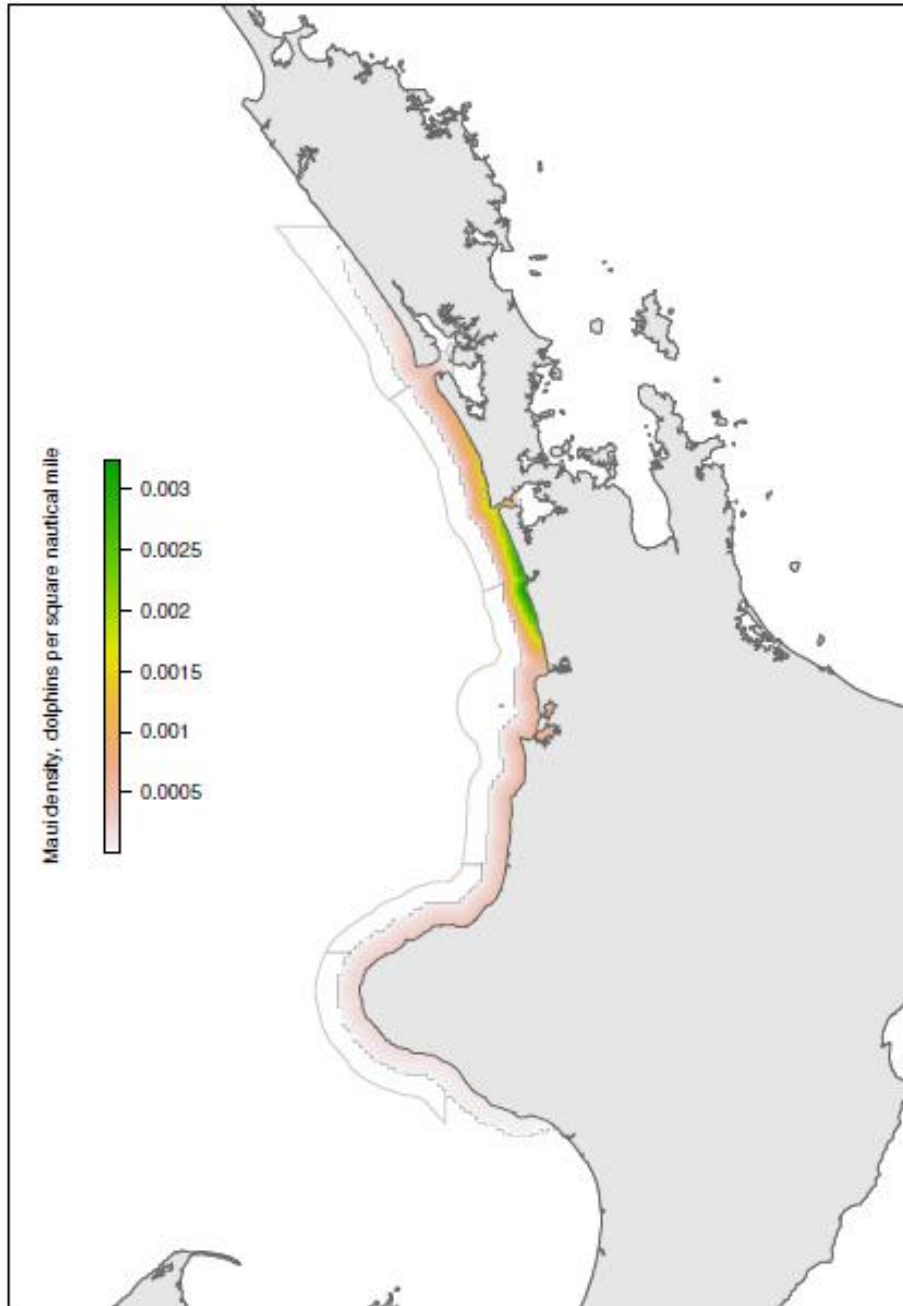
Figure 2b. Maui's dolphin distribution to 7 nmi from shore as determined by Currey et al. (2012) based on nine aerial and biopsy surveys conducted between 2000 and 2012 as well as other sightings data. Colors represent the expected number of dolphins per square nmi. The outer gray line represents the boundary for the West Coast North Island Marine Mammal Sanctuary. (Taken from Currey *et al*. 2012.)
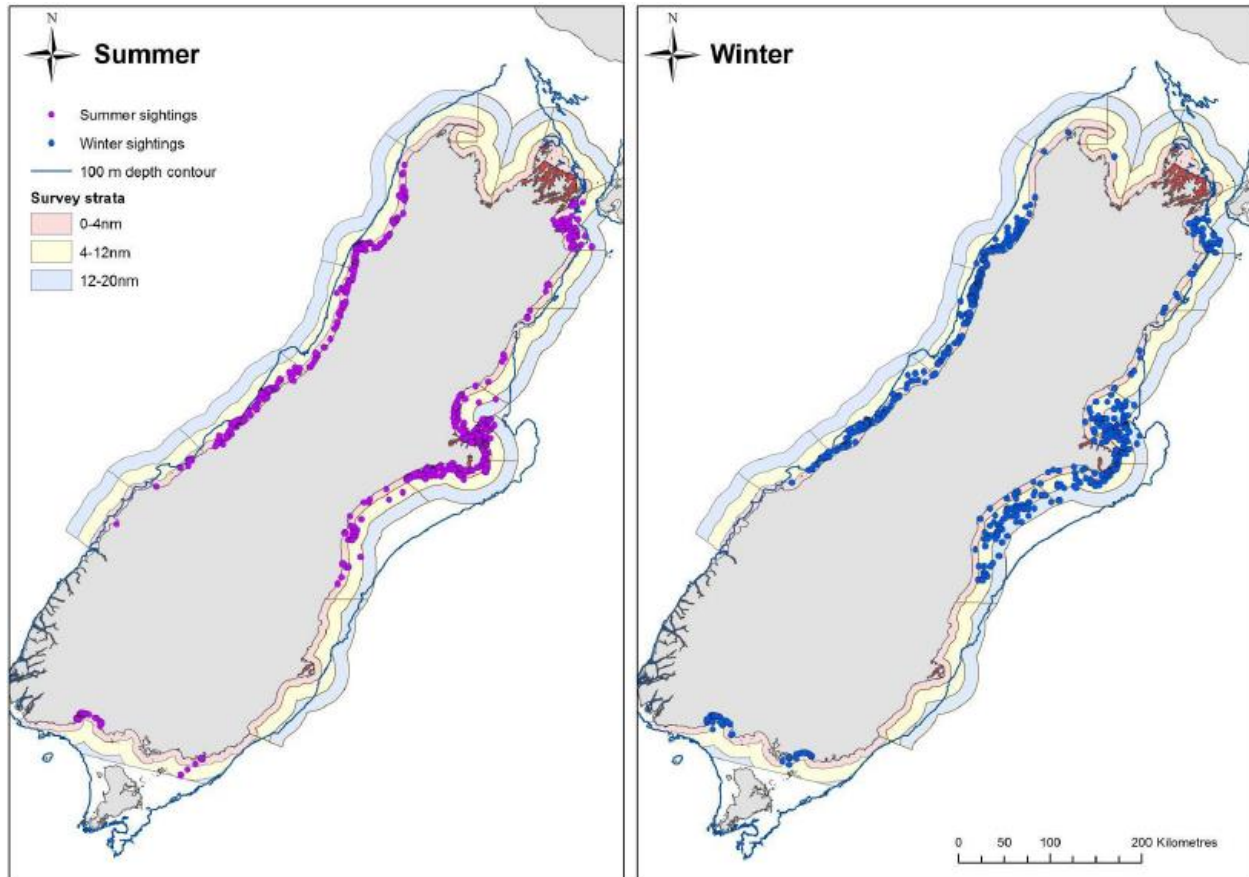
Figure 2c. Summer and winter sightings of SI Hector's dolphins during separate aerial surveys conducted between 2010 and 2015. Shaded zones along each coast indicate boundaries of the survey strata. (Taken from Mackenzie and Clement 2016).

Seasonal changes in this nearshore distribution are evident for at least some populations of Hector's dolphins. Aerial surveys that extended as far as 20 nmi offshore (37 km) of Banks Peninsula were conducted over three years (2002, 2004, and 2005) and indicated that although SI Hector's dolphins were most common closest to shore in both summer and winter, the dolphins became much more evenly distributed with respect to distance from shore and extended farther offshore and into deeper waters in winter (Rayment *et al*. 2010b). Sightings extended as far as 18.2 nmi (33.6 km) offshore in winter and 16.3 nmi (30.2 km) in summer. While only 7% of all dolphins were sighted beyond the 50 m isobath in summer, 44% of all dolphins were sighted beyond the 50 m isobaths in winter (Rayment *et al*. 2010b). Slooten *et al*. (2005) report a similar change in distribution for Maui's dolphins between summer and winter aerial surveys. Aerial surveys from New Plymouth to Maunganui Bluff in 2004 indicated that about 75% of the sightings occurred within 1 nmi (1.85 km) of shore in the summer, compared to only 33% in the winter (Slooten *et al*. 2005). As in the case of the Banks Peninsula study, the

maximum offshore distance for Maui's dolphins was very similar during these winter and summer surveys (3.33 nmi (6.17 km) versus 3.09 nmi (5.72 km), respectively).

Similar but less substantial seasonal changes in SI Hector's dolphin distribution relative to shore or water depth have been detected on the west coast of the South Island (Rayment *et al*. 2011b, MacKenzie and Clement 2016). Aerial surveys conducted in 2004/2005 along almost the entire west coast and out to 20 nmi (37.0 km) offshore showed that, in both summer and winter, dolphin densities declined steadily with distance from shore, with a mean distance from shore of 1.8 nmi (3.3 km) in summer and 2.8 nmi (5.1 km) in winter (MacKenzie and Clement 2016). Approximately 70% of all sightings were within waters less than 30 m deep in summer, compared to 57% of all sightings in winter (Mackenzie and Clement 2016).

Seasonal changes in the distribution of Hector's dolphins may correspond to changes in prey distributions (Brager *et al*. 2003, Rayment *et al*. 2010b, Miller *et al*. 2013, Dawson *et al*. 2013). Evidence in support of this hypothesis comes from trawl surveys of fish assemblages along a portion of the east cost of the South Island that indicate, in winter, the preferred water depth increased for the majority of the most abundant fish species, including red cod (*Pseudophycis bachus*), an important prey species for Hector's dolphins (Slooten and Dawson, 1994; Dawson and Slooten 1996, Beentjes *et al*. 2002). Likewise, commercial fishing on species such as red cod also shifts to deeper waters with the change in seasons (Beentjes *et al*. 2002). Another potential explanation for the inshore distribution of Hector's dolphins in the summer is that the shallower, warmer, more protected nearshore waters are preferred by mature females for calving and nursing (Rayment *et al*. 2010b), as has been well described in other cetaceans, because such habitat reduces the energetic demands on nursing mothers and their calves.

An additional and related explanation for the observed regional variation in distribution patterns of Hector's dolphins is the differences in bathymetry among geographic regions (Rayment *et al*. 2011b). On the west coast of the South Island, where the dolphins do not tend to undergo as large of a seasonal onshore-offshore change in distribution, the shelf is much steeper than it is along the east coast. On the west coast, the 100 m isobath is always within 13 nmi (24.08 km) of the coast and in some places as close as 5 nmi (9.26 km); whereas, off Banks Peninsula on the east coast, the 100 m isobath is 16 to 30 nmi (29.63 to 55.56 km) offshore (Rayment *et al*. 2011b). Studies by Rayment *et al*. (2010b, 2011b) indicated that SI Hector's dolphins occurred as far as 18.2 nmi (33.71 km) offshore on the east coast of the South Island, compared to less than 6 nmi (11.11 km) on the west coast, and - in these particular studies - no sightings occurred on either coast where water depths were greater than 90 m. Recently, however, during aerial surveys along the west coast, MacKenzie and Clement (2016), sighted several SI Hector's dolphins as far as 9.6 nmi from shore (17.7 km) and in waters as deeper than 100 m. Thus, while bathymetry and shelf breaks helps explain the general distribution patterns,

the dolphins' distributions are obviously not strictly bound by water depth or distance from shore.

Diurnal distribution patterns have also been described but these patterns are not yet fully resolved. Over the course of 19 days in summer of 1993/94, Stone *et al.* (1995) conducted land-based observations of SI Hector's dolphin movements from cliffs over Akaroa Harbor, a small harbor on Banks Peninsula, to evaluate nighttime movements of the dolphins and determine whether there is a diurnal offshore movement out of the harbor. Stone *et al.* (1995) found that the dolphins tended to swim inshore in the morning and offshore at night, and that swimming direction was non-random (χ^2 = 62.44, p=0.001, α = 0.05). However, in their land-based surveys conducted over two summers in Porpoise Bay, which lies along the southeast coast of the South Island, Bejder and Dawson (2001) found no diurnal movement of the dolphins into and out of the bay. Likewise, acoustic surveys in Akaroa Harbor show a diurnal shift in the dolphins' distribution towards the outer harbor at night but no evidence for leaving the harbor at night (Dawson et al. 2013).

Other factors that may influence finer scale habitat selections or preferences of Hector's dolphins are not yet clear. Brager *et al.* (2003) evaluated habitat preference using a logistic regression model and dolphin sightings and environmental data (water depth, water clarity, and sea surface temperature) collected at three sites along both the east and west coasts of the South Island and concluded that water depth, water clarity, and sea surface temperature significantly affect habitat selection by SI Hector's dolphins. Based on this study, the dolphins preferred habitats with water depths less than 39 m, visibility less than 4 m, and sea surface temperatures greater than 14°C (Brager *et al.* 2003). Derville *et al.* (2016) examined environmental correlates with Maui's dolphin summer distribution and reported that summer distribution is partly explained by sea surface temperature (22.6%), water turbidity (22.2%), and distance to major watersheds (17.0%), water depth (14.5%), distance to minor watersheds (13.3%), and distance to the coast (10.4%). Both subspecies have often been sighted near river mouths and estuaries within turbid waters (Abel *et al*. 1971; Baker 1972, 1978; Mörzer-Bruyns and Baker 1973). For example, Baker (1978) noted that Hector's dolphins are often seen in "muddy or discolored water seaward of estuaries and deep inlets." More turbid waters may increase hunting efficiency by the dolphins and are possibly correlated with river mouths, explaining Baker's (1978) observation. Ferreira and Roberts (2003), who conducted aerial surveys over two summers (2000/01 and 2001/02) along the west coast of the North Island, concluded that although the Maui's dolphins showed no preference for turbid waters associated with river mouths or harbors, the dolphins did appear to be associated with turbid waters, which actually characterize much of that coast. Dawson and Slooten (1988b) also commented that the reported observations of Hector's dolphins in association with turbid

water may simply reflect the dolphins' preference for nearshore waters, which happen to be relatively turbid in coastal New Zealand.

Hector's dolphins have relatively small home ranges and high site fidelity. Based on an analysis of summer and some limited winter sightings of photo-identified SI Hector's dolphins at Banks Peninsula from 1985 to 1997, Bräger *et al.* (2002) reported that the average distance between sightings of individuals was 31 km (SE= 2.43, n=32 dolphins). All of the dolphins monitored in this study ranged over distances shorter than 60 km along the coast, except for one dolphin that had two sightings 106 km apart (Bräger *et al*. 2002). On average, all dolphins occurred within Akaroa Harbor during 65% of the summers and six dolphins in particular were sighted there every summer of the study, suggesting high site fidelity to this small harbor along the southern coast of Banks Peninsula. Bedjer and Dawson (2001) reported a similarly high degree of summer residency in Porpoise Bay: seventy-five percent of the photo-identified dolphins returned to this bay in two consecutive summers, and while in the bay, the dolphins used only a very small portion of the bay. Rayment *et al.* (2009a) extended the work of Bräger *et al.* (2002) by using photo-identification data collected at Banks Peninsula from 1985 to 2006. Using the same methods as Bräger *et al.* (2002), Rayment *et al.* (2009) calculated a very similar average along-shore home range of 33.01 km (SE = 2.27) based on 53 dolphins that were sighted an average of 15 times (SD = 5.07). Univariate kernel density estimates were also calculated for 20 dolphins that had 15 or more sightings. The 95% density estimate (K_{95}), which was used as the measure of the alongshore range was 49.69 km (SE= 5.29). "Core" areas, or portions of coastline containing 50% of the density distribution (K_{50}), ranged from 5.35km to 35.38km in length and were distributed around four, specific centers of activity, indicating a fairly consistent and clumped distribution (Rayment *et al*. 2009a). There were no significant differences in the K_{95} and K_{50} of males (n=7) versus females (n=11) (Rayment *et al*. 2009a).

An along-shore home range estimate for Maui's dolphins was generated by Oremus *et al.* (2012) using genetic recapture data collected over two summers (2010 and 2011) along the west coast of the North Island. Using the largest distances between locations of recaptures for 6 dolphins (3 females and 3 males) sighted 3 to 4 times, Oremus *et al.* (2012) calculated a minimum along-shore home range of 35.5 km (SE= 4.03). However, one dolphin travelled 78 km over 19 days, suggesting individual home ranges vary (Hamner *et al.* 2012b).

Based on these studies, the along-shore home range appears to be similar for both subspecies and is typically less than 50 km (Rayment *et al*. 2009a, Oremus *et al*. 2012). Home ranges also do not appear to differ between males and females (Brager *et al.* 2002, Rayment *et al.* 2009a).

Longer-range movements of SI Hector's dolphins do appear to occur, at least on occasion. Recent genetic data indicate that two female SI Hector's dolphins were living within the range of Maui's dolphins, and four dead SI Hector's dolphins were found along the coast of the North Island (Hamner *et al.* 2012b, Hamner *et al.* 2014a). These data suggest that there may be long-distance (> 400 km) dispersal of SI Hector's dolphins. However, there has been no documented mating between the two subspecies of Hector's dolphins (Hamner *et al*. 2012b, Hamner *et al*. 2014a).

2.3 Population Structure and Genetic Diversity

Along with other lines of evidence, genetic evidence of reproductive isolation was used to support the formal recognition of Maui's dolphins as a subspecies in 2002 (Baker *et al.* 2002, Pichler 2002). Analyses of both maternally inherited mitochondrial DNA (mtDNA) and bi-parentally inherited nuclear DNA, have consistently indicated a high level of genetic differentiation of Maui's dolphins from SI Hector's dolphins and extremely limited gene flow between the two subspecies (Pichler and Baker 2000, Pichler 2002, Hamner *et al.* 2012a). An analysis by Hamner *et al.* (2012b) of a 650 basepair (bp) fragment of control region mtDNA from stranded and biopsied Maui's (n=70) and SI Hector's dolphins (n=318) confirmed earlier findings that Maui's dolphins were fixed for a single haplotype (G haplotype, Figure 3) that has not been observed in the SI Hector's dolphins in any study. Comparisons of 9-locus microsatellite genotypes between Maui's dolphins and SI Hector's dolphins by Hamner *et al.* (2012a) provide additional evidence of a high degree of genetic differentiation (F_{ST} = 0.167, p < 0.001; see also Figure 4) and no evidence of migration between the two subspecies (migration rate = 0.006 (SE=0.006) to 0.007 (SE= 0.007), using BayesAss v3.0 and the 9-locus genotype dataset). Earlier estimates by Pichler (2002) of effective biparental migration rates per generation (7 years) between Maui's dolphins and populations of SI Hector's dolphins were similarly low (N_m = 0.154 – 0.318) and indicated little to no dispersal between the subspecies.

Genetic diversity in Maui's dolphins is currently very low. Pichler (2002) analyzed microsatellite DNA for Maui's dolphins across six loci (n = 4 to 12) and reported an average of 1.5 alleles per locus, three of which were fixed (i.e., 1 allele), and an overall low heterozygosity (0.083 – 0.25). In addition, as already discussed, the contemporary mtDNA data reflect a single maternal lineage (Pichler 2002, Hamner *et al.* 2012a). This level of haplotype diversity (i.e., *h* = 0) is well below the expected range of 0.70 – 0.92 for other, abundant odontocete species (Pichler and Baker 2000). Interestingly, in an analysis of a 550 bp fragment of the maternally inherited mitochondrial DNA (mtDNA) control region, Pichler (2001, 2002) detected 3 haplotypes in samples of Maui's dolphins (n=29) that included both contemporary (n=26, from 1988-1998) and historical samples (n=3, from1870-1987). Only the historical samples (n=3), which were

obtained from museums, had haplotypes other than the "G" haplotype found in contemporary samples, suggesting a historically recent loss in mtDNA diversity (Pichler 2001, 2002; Pichler and Baker 2000). However, as discussed thoroughly in Baker *et al.* (2002) and Hamner *et al.* (2012a), there is considerable doubt regarding the actual source population of those three historical samples.

Based on genotyping of 46 samples of Hector's dolphins collected off the North Island from 2010- 2012, Hamner *et al.* (2014a) detected two, female SI Hector's dolphins living in association with Maui's dolphins - one of which was observed with Maui's dolphins in two consecutive years. An additional two dead dolphins sampled from within the Maui's dolphin range and two dolphins (one dead female neonate and one living male) from the previously unsampled southwest coast of the North Island represented haplotypes only seen in the SI Hector's subspecies (C, H, I, and J), and all four of these dolphins were assigned by *Structure* analysis to the SI Hector's dolphin subspecies (Hamner *et al.* 2014a). Although there was no evidence of interbreeding, this finding does indicate several living SI Hector's dolphins have completed a minimum 216 nmi (400 km) migration to reach the North Island. These authors called for continued genetic monitoring of Maui's dolphins to track these potential immigration events.

In addition to the substantial genetic differentiation between the two subspecies, there is also clear evidence of regional population structuring within the South Island subspecies (Pichler *et al.* 1998, Pichler 2002, Hamner *et al.* 2012a). Analyses of both mtDNA and microsatellite DNA indicate the existence of three regional populations, referred to as the east coast (EC), west coast (WC), and south coast (SC) populations. Twenty different mtDNA haplotypes were observed in the SI Hector's dolphins samples (n= 318) analyzed by Hamner *et al.* (2012a), and each regional population was characterized by one or two high frequency haplotypes (Figure 3). Pairwise comparisons of 13-locus microsatellite genotypes of SI Hector's dolphins also indicated a significant level of genetic differentiation among the three major regional populations (i.e., EC, WC, and SC; F_{ST} = 0.039 to 0.071, p < 0.001 for all comparisons, Hamner *et al.* 2012a). Structure analysis of the 13-locus genotype data indicated very strong assignment of individual dolphins to the region where they were sampled but also indicated possible migration among regions (Figure 5). Interestingly, the two sample populations within the SC region (Te Wæwæ Bay (TW) and Toetoe Bay (TB), Figure 3) were significantly differentiated based on both mtDNA (F_{ST} = 0.136; p = 0.03) and microsatellite DNA (F_{ST} = 0.043; p = 0.005) even though they are separated by only about 100 km of coast (Hamner *et al.* 2012a). Fine-scale population

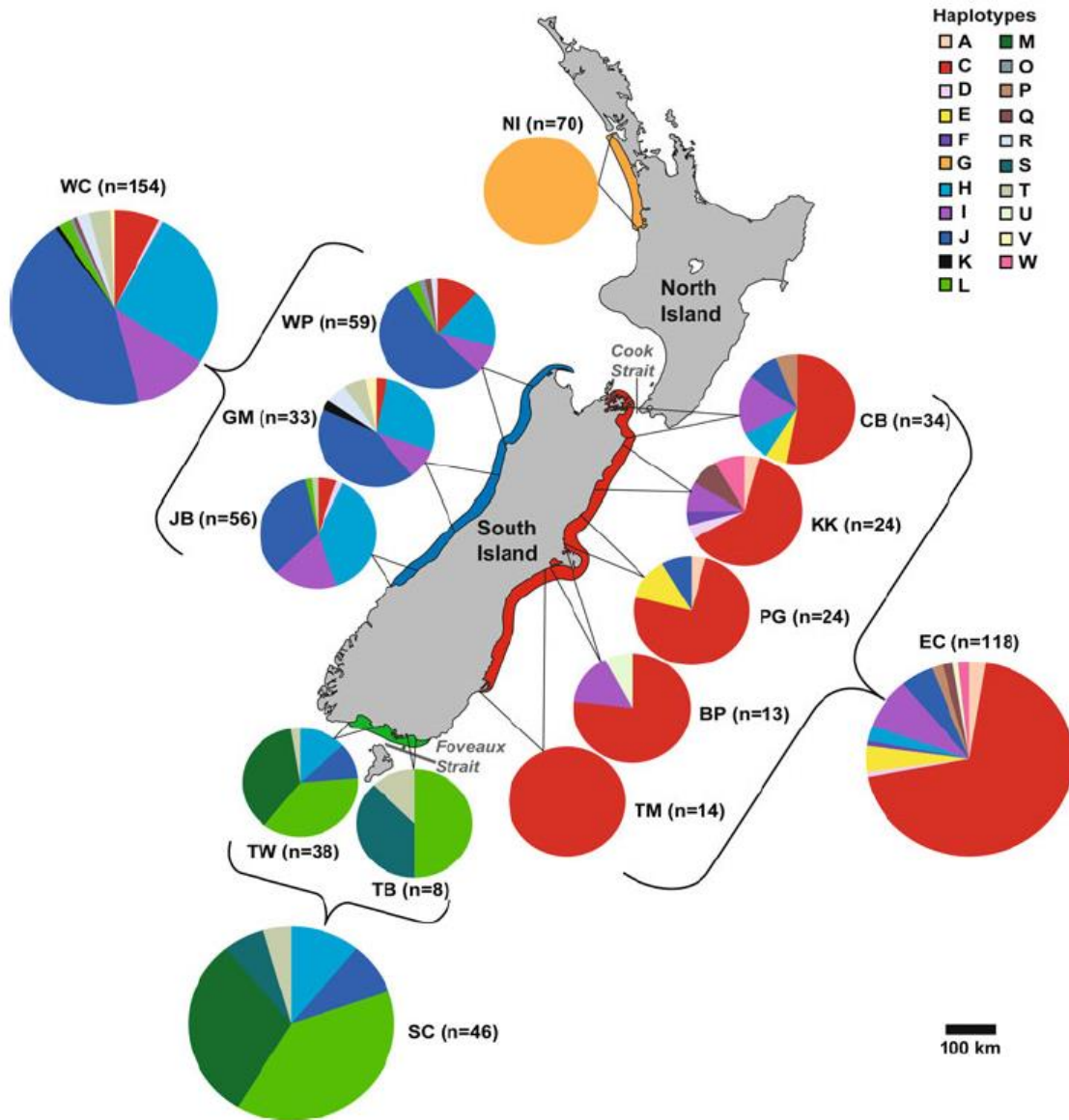**Figure 3**. Distribution of mtDNA control region haplotypes (360 bp) for Maui's on the North Island (NI) and SI Hector's dolphin populations on the East Coast (EC: Cloudy Bay (CB), Kaikoura (KK), Pegasus Bay (PG), Banks Peninsula (BP), and Timaru (TM)), the West Coast (WC: Westport (WP), Greymouth (GM), and Jackson Bay (JB)), and the South Coast (SC: Te Wæwæ Bay (TW) and Toetoe Bay (TB)). Taken from (Hamner *et al*. 2012a).
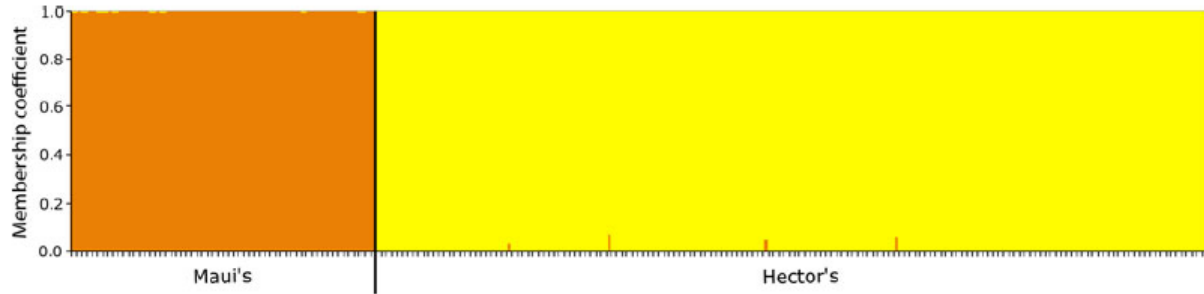
Figure 4. Assignments of Maui's (orange) and SI Hector's (yellow) dolphins based on *Structure v2.3.2* analysis of 9-locus microsatellite genotypes. Each vertical bar represents an individual dolphin and is colored according to each individual's coefficient of membership to a particular subspecies. (From Hamner *et al.* 2012a).
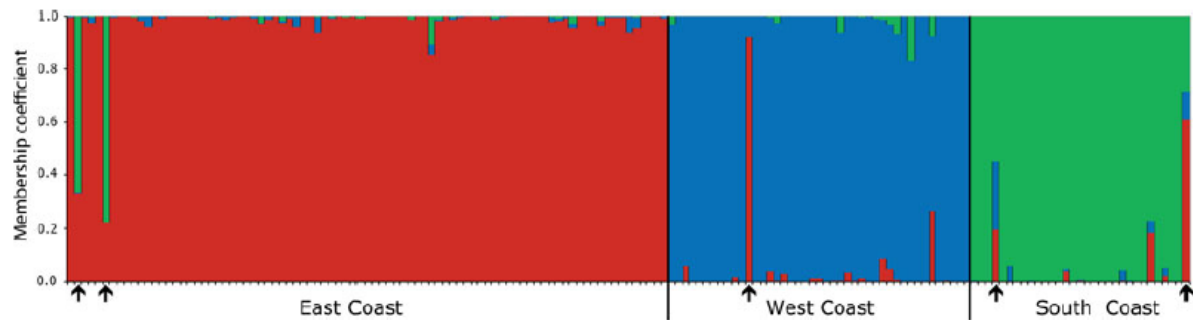
Figure 5. Assignment of dolphins to the East (red), West (blue), and South (green) Coast regional population based on *Structure v2.3.2* analysis. Each vertical bar represents a single dolphin and is colored according to its coefficient of membership to a particular regional population. Arrows along the x-axis indicate possible F1 migrants that, based on their mtDNA haplotypes, may have been produced by immigrant males and resident females. From Hamner *et al.* (2012a).

structuring has also recently been detected in the EC SI Hector's dolphins sampled on either side of Kaikoura Canyon on the northeast coast (n= 117, Hamner et al. 2016). Analysis of both mtDNA (F_{ST} = 0.081, p < 0.001) and microsatellite DNA (F_{ST} = 0.013, p < 0.001) indicated a low but statistically significant level of genetic differentiation between these adjacent sample populations (Hamner *et al*. 2016).

Analysis of levels of genetic differentiation among local populations around the South Island suggests a stepping-stone model of gene flow in which there are low levels of migration between neighboring populations, but much more limited gene flow among the three larger regional populations (Pichler 2002; Hamner *et al.* 2012a). In particular, Hamner *et al.* (2012a) estimated low inter-region migration rates ranging from 0.007 (SE = 0.007) to 0.189 (SE = 0.078)

and concluded that very rare migration events were facilitating gene flow across the roughly 100- 370 km distances separating them.

Although genetic diversity of SI Hector's dolphins is higher than Maui's dolphins, it is relatively low compared to other dolphin species (Pichler and Baker 2000, Pichler 2002). For example, Pichler and Baker (2000) reported haplotype (h) and nucleotide (π) diversity estimates of 0.35 and 0.30%, respectively, for EC Hector's dolphins (n=46) and 0.66 and 0.40% for WC Hector's dolphins (n= 47), which are low compared to previously reported estimates for other, more abundant odontocetes (e.g., h = 0.70 - 0.92 and π > 1.0%). Diversity estimates based on mtDNA analyses by Hamner *et al*. (2012a) were somewhat higher for both the EC (h = 0.51, π= 0.39%) and WC (h =0.72, π= 0.49%, n= 154) populations, possibly as a consequence of larger sample sizes, but are still relatively low. Based on an analysis of mtDNA samples for EC Hector's dolphins, Pichler and Baker (2000) reported a possible decline in mitochondrial diversity between historical samples from 1870-1987 (h=0.652 and π=0.0084, n=36) compared to more contemporary samples from 1988-1998 (h=0.350 and π=0.0030, n=46) and that the most common lineage had increased its representation from 58% to 80% between the two time periods. These authors suggested that the observed rate of decline in genetic diversity indicates an ongoing decline in population abundance.

2.4 Reproduction, Growth, and Longevity
Based on examination of reproductive tracts combined with an analysis of tooth sections for 60 stranded and incidentally killed Hector's dolphins (33 females, 27 males), Slooten (1991) concluded that females have their first calf at 7-9 years of age, and that males likely reach sexual maturity at 6 -9 years of age. Because the dolphins in this study had been found stranded on beaches or were obtained from fishermen who had incidentally caught the dolphins in their nets, the source populations of the dolphin carcasses is not clear. Using data from a long-term mark-recapture studies and autopsies of SI Hector's dolphins off Banks Peninsula, Gormley (2009) estimated mean age at sexual maturity for females as 7.55 years old (n= 117, 95% CI = 6.71 – 8.41).

Mating is typically observed in the fall and winter, with a peak in mating behavior in the early winter (Slooten and Dawson 1988). Calving occurs in the austral spring and early summer, generally from November to February (Slooten and Dawson 1988, Slooten and Dawson 1994). Females typically produce single calves every 2 to 4 years (Slooten and Dawson 1994), which gives a yearly birth rate between 0.33 and 0.5. Assuming a 1:1 sex ratio, fecundity (i.e., the number of female offspring per female per breeding season) was estimated as 0.165 to 0.25 (Secchi *et al.* 2004b). A more recent fecundity estimate for SI Hector's dolphins off Banks

Peninsula of 0.205 (95% CI = 0.129 – 0.324) is in general agreement with earlier estimates (Gormley 2009).

Calves remain with their mothers for 1 to 2 years, although 2 years appears to be more common (Slooten and Dawson 1994). Weaning may occur around 12 months after birth, as suggested by Miller's (2013) stomach content study in which a 1-year old Hector's dolphin was observed with milk and arrow squid beaks in its stomach. There have been no observed cases of overlap between lactation and pregnancy in a single female (Slooten 1991a, Gormley 2009).

Through analysis of growth layers in tooth dentine, Slooten (1991) observed a maximum female age of 20 years (n=33) and a maximum male age of 19 years. In subsequent examinations of stranded and bycaught SI Hector's dolphins, Secchi *et al.* (2004b) and Gormley (2009) applied the same aging technique as in Slooten (1991) and found that the oldest male in the sample was 20 years old (n=62) and the oldest female was 19 years old (n=46). In field studies off Banks Peninsula, four Hector's dolphins with a minimum age of 22 years have been aged based on photo-identification data (Rayment *et al.* 2009a, Webster *et al.* 2009, Gormley *et al.* 2012). Thus, maximum age is at least 22 years.

2.5 Diet and Feeding

Hector's dolphins have a varied diet that includes cephalopods, crustaceans, and small fish species; however, relatively few prey species appear to comprise the bulk of their diet. In an analysis of stomach contents from 63 stranded or bycaught Hector's dolphins collected between 1984 and 2006, Miller *et al.* (2013) found that the most common prey items (by number and mass) of 29 taxa identified were red cod (*Pseudophycis bachus*), ahuru (*Auchenoceros punctatus*), arrow squid (*Nototodarus* sp.), sprat (*Sprattus* sp.), sole (*Peltorhamphus* sp.), and stargazer (*Crapatalus* sp.). Red cod contributed the most by mass (37%) and ahuru contributed the most by number to the stomach contents (Miller *et al.* 2013). Although prey sizes ranged up to 60.8 cm long, over 75% of the prey items were less than 10 cm long (Miller *et al.* 2013). The dolphins used in this study came mainly from the east coast of the South Island (n=36), but others were collected from the west (n=23) and south (n=2) coasts of the South Island, and the west coast of the North Island (n=2), so the diet information from this study is generally applicable across the range. However, differences in stomach contents were observed between the east and west coasts of the South Island and may reflect differences in prey availability. For example, a significantly greater number and mass of javelinfish (*Lepidorhynchus denticulatus*, p=0.003) and a greater number of anchovy (*Engraulis australis*, p=0.002) occurred in the stomach contents from the west coast (Miller et al. 2013). In addition,

the east coast stomach contents contained a significantly greater number of demersal species when compared to the west coast (p=0.001; Miller *et al.* 2013).

The stomachs of the six smallest dolphins in Miller *et al*.'s (2013) study (standard length (SL) less than 90 cm) contained only milk. The stomach contents of the next largest dolphin (99 cm SL) included a mix of milk and arrow squid, and no milk was detected in stomach content of dolphins longer than 107 cm (SL) (Miller *et al*. 2013).

The stomach contents documented by Miller *et al.* (2013) indicate that Hector's dolphins feed throughout the water column but appear to focus on mid-water and demersal prey species (Miller *et al*. 2013). Surface feeding is not common but has been observed, and cooperative feeding (e.g. herding) has only rarely been observed (Miller *et al*. 2013). Aggregations of Hector's dolphins have been observed following inshore trawling vessels, presumably to take advantage of injured, disoriented, or possibly even entangled prey (Slooten and Dawson 1988, Rayment and Webster 2009c). White fronted terns (*Sterna striata*) are also fairly commonly seen in association with groups of Hector's dolphins feeding on seasonally abundant small fish prey near the surface of the water in spring and summer (Bräger 1998b).

2.6 Social Structure and Behavior

Hector's dolphins are typically observed in small groups averaging about 2 to 4 dolphins and ranging up to about 16 dolphins (Rayment *et al*. 2011b, Oremus *et al*. 2012, MacKenzie and Clement 2016); although, larger, loose aggregations of over 20 dolphins have also been observed (Baker 1978, Slooten and Dawson 1988, Webster *et al*. 2009). Within these larger, usually temporary, social aggregations, merging and splitting of small groups is frequently observed (Slooten and Dawson 1988). Studies examining the nature of associations between individual SI Hector's dolphins suggest that only weak social associations form and that SI Hector's dolphins live in a dynamic or "fission-fusion" society marked by short-term (days) associations within a larger community or population (Slooten *et al*. 1993, Bräger 1999a).

Results from a study conducted at Banks Peninsula using an underwater video camera suggest that small groups of SI Hector's dolphins are often segregated by sex (Webster *et al*. 2009). Groups containing mothers and their calves contained no adult males, and 91% of groups with two to five individuals (n=43) were single-sex (Webster *et al*. 2009). Larger groups tended to be of mixed-sex, but as 82.8% of groups observed had fewer than 6 members, the majority of observed groups were sexually segregated. There were no differences in habitat use or home range observed between the groups (Webster *et al.*, 2009).

Hector's dolphins have been described as 'quiet swimmers' that rarely jump fully out of the water (Baker 1978) and are usually less active than dusky dolphins or spinner dolphins. However, they do display a wide range of behaviors, including body contacts, bubble-blowing, leaping, lobtailing (slapping the water surface with the fluke), and spyhopping (holding the body vertically with head above the water surface; Slooten and Dawson 1988). Jumping out of the water and lobtailing (i.e., tail raised out of the water and deliberately slapped on the water surface) may be more commonly associated with sexual and aggressive behaviors (Slooten 1994). Hector's dolphins seem curious and are attracted to small boats, especially slow-moving (less than 10 knots) boats; and they prefer to swim in the wake of slower-moving boats, rather than bow-ride (Baker 1978, Slooten and Dawson 1988).

2.7 Acoustics

The acoustic repertoire of Hector's dolphins consists mainly of high frequency (112-130k Hz) clicks of either one or two short pulses (i.e., usually less than <200 µs for single pulses and <400 µs for double pulses, Dawson 1988a). They make very few audible sounds and do not produce whistles (pure, lower-frequency tones, usually between 5 to 15 kHz) like most delphinid cetaceans (Dawson 1991a). Occasionally, pulses can occur in such rapid succession within a train of pulses that they generate an audible "cry" or "squeal" sound (Dawson 1991a, citing Watkins *et al.* 1977). Analysis of recorded vocalizations suggests Hector's dolphins use their vocalizations for fine discrimination, locating prey, and communicating, rather than large-scale navigation, for which lower frequency echolocation is required (Dawson 1988a, Dawson 1991a). Dawson (1991a) also found that more complex sounds, with more than two peaks in their spectra, were used mostly in large group settings, and thus presumably serve a social function. High pulse rate sounds or "cries" were observed more often during aerial displays and aggressive behavior, suggesting that these indicate either positive or negative excitement depending on the context (Dawson 1991a).

2.8 Abundance and Trends

A number of abundance estimates have been generated for both Maui's and SI Hector's dolphins using a variety of survey methodologies (Tables 1 and 2). The earliest survey of Hector's dolphins was conducted by Dawson and Slooten (1988) in 1984/85 and covered both the North and South Island. Using a small boat, Dawson and Slooten (1988) surveyed the west coast of the North Island and the entire coast of the South Island, with the exception of Fiordland and Stewart Island, where sightings are rare. Based on results of their coastal strip-transect surveys, which were concentrated within 800 m of the coast, Dawson and Slooten (1988) roughly estimated a total abundance of 3,408 dolphins. By island, their abundance estimate included 3,274 dolphins for waters off the South Island and 134 dolphins for the North Island. (Existing methodology at that time precluded calculation of confidence intervals.) Using

more advanced methodologies, a series of small boat and aerial line transects were completed in the late 1990s and early 2000s, and produced an estimate of 7,270 dolphins throughout the South Island (95% CI = 5,303 – 9,966, CV=16.2%, Slooten *et al.* 2004, Dawson *et al.* 2004, Dawson *et al.*, 2000, Clement *et al.*, 2001, Du Fresne *et al.*, 2001a, Slooten *et al.*, 2002) and 111 dolphins in the North Island (95% CI = 48- 252, CV=44%, Slooten *et al.*, 2006). Later surveys, which increased in sophistication both in terms of the survey design and data analysis, are discussed in more detail below.

2.8.1 Maui's Dolphins

The most recent abundance estimate for Maui's dolphins over one-year of age is 55 (95% CI= 48-69, Hamner *et al*. 2012b; Hamner *et al.* 2014b). This estimate is based on a genetic mark-recapture analysis using 37 biopsy samples collected in 2010 and 36 biopsy samples collected in 2011, which were genotyped across 20 variable microsatellite loci and analyzed in a closed-sample model (Lincoln-Peterson estimator with Chapman correction, Chapman 1951; Hamner *et al*. 2014b). Based on genetic identification of individuals sampled across the two years, the minimum census size was determined to be 42 dolphins (25 females, 17 males; Hamner *et al*. 2012b). The effective population size for 2010-2011 – or the predicted number of breeding adults in the parental generation – was estimated (using linkage disequilibrium method, Waples and Do 2008) to be 69 dolphins (95% CI = 31- 641), which is high relative to the estimated mark-recapture abundance but may indicate a decline from the 2001-2007 effective population size (Hamner *et al*. 2012b).

To evaluate population trends, Hamner *et al.* (2012b) also genotyped 70 archived biopsy samples collected during small boat surveys in 2001 to 2006 and an additional 13 samples collected between 2001 and 2010 during necropsy of stranded or entangled dolphins. Capture histories were then created for individual dolphins, and survival *(phi)* and the annual rate of change in the population (*lambda*) were estimated by running and evaluating a series of models using the Pradel Survival and Lamba framework in MARK v5.1 (see Hamner *et al*. 2012b). Based on the model results, the annual rate of change was estimated to be 0.97 (95% CI= 0.89 – 1.06) and annual survival rate was estimated to be 0.83 (95% CI = 0.75 – 0.90). The estimated annual rate of change suggests a population decline of 3% per year; however, the large confidence interval precludes a firm conclusion. The estimated survival rate suggests an annual mortality rate of 17% per year for ≥ 1 year-old dolphins (Hamner *et al*. 2012b). The estimated survival rate of 0.83 is fairly precise and consistent with previous estimates for SI Hector's dolphins ≥ 1 year old (e.g., 0.77 – 0.89, Slooten and Lad 1991, Cameron *et al*. 1999, Slooten *et al*. 1992, Slooten and Dawson 1994).

Hamner *et al.'s* (2014b) population estimate of 55 Maui's dolphins for 2010-2011 is lower than, but within confidence intervals of, earlier abundance estimates calculated by (Baker *et al*. 2013)

using the same general methodology for the Maui's population in 2001 to 2007. In Baker *et al.*'s (2013) study, biopsy samples of 70 live and 12 dead Maui's dolphins were genotyped across up to 14 microsatellite loci (compared to 20 microsatellites used in Hamner *et al.* 2012b). Using a POPAN model (in program MARK), Baker *et al.* (2013) estimated a total abundance of 87 Maui's dolphins (95% CI = 59 -158) across the entire sample period. Annual estimates of abundance were then derived to examine population trends. For 2001, the abundance estimate for the population was 87 (95% CI = 62 - 121) based on the POPAN model, which used only live capture data, and 91 (95% CI = 47 – 176) in a Pradel-like model, which used both live and stranded sample data. For the latest year in the study period (2006), the abundance estimate based on the POPAN analysis was 59 (95% CI= 19 – 181), and using the modified Pradel model was 46 (95% CI = 13- 167). Both of these estimates are in line with that of Hamner *et al.*'s (2014b) estimate of 55 dolphins in 2010-2011, especially given the confidence intervals around each estimate. The Pradel-like model results of Baker *et al.* (2013), however, suggest a much steeper population decline over the study period of 13% per year (versus -3% based on Hamner *et al.* 2012b); although again, it was not possible to confirm a population decline given the large, associated 95% confidence interval of -40% to +14% (Baker *et al.* 2013).

Although neither genetic mark recapture study could confirm a declining trend with 95% confidence, the apparent population decline suggested by these studies is consistent with a meta-analysis by Wade *et al.* (2012). As part of a larger risk assessment for Maui's dolphins, Wade *et al.* (2012) conducted a trend analysis using abundance estimates produced in six different studies completed from 1985 to 2011. Using linear regression of the natural logarithm of the estimated abundance, Wade *et al.* (2012) calculated a statistically significant declining trend of -3.2% per year (90% CI = -5.7% - -0.6%, p = 0.029). Wade *et al.* (2012) noted that the abundance trend could be interpreted as having a 97.1% probability of being less than zero. This estimated rate of decline is also very similar to the 3% per year decline estimated by Hamner *et al.* (2012b).

Table 1. Summary of abundance estimates (N) for Maui's dolphins. General information regarding survey method is provided. Because survey methodologies vary among studies, results are not necessarily comparable.

Sampling Period	Research Method	N	95% Confidence Interval	Reference
1985	small boat, strip transects	134	N/A	Dawson & Slooten 1988
1985	small boat, strip transect	140	46-280	Martien *et al*. 1999
1998	Small boat	80	N/A	Russell 1999
2001/02	aerial transect	75	48 - 130	Ferreira & Roberts 2003
2001	genetic capture recapture	87	62 - 121	Baker *et al.* 2013
2004	aerial transect	111	48 - 252	Slooten *et al.* 2006
2006	genetic capture recapture	59	19 - 181	Baker *et al.* 2013
2010-2011	genetic capture recapture	55	48- 69	Hamner *et al.* 2014b

2.8.2 SI Hector's Dolphins

The first line-transect survey for the total SI Hector's dolphin population extended 4 nmi (7.4 km) from shore and resulted in an abundance estimate of 7,270 (95% = 5,303 – 9,966, Slooten *et al*. 2004). This abundance estimate was based on boat surveys conducted between 1997 and 2001 along the north, east, and south coasts of the South Island (Dawson *et al*. 2004), and an aerial survey of the west coast conducted in 2000 (Slooten *et al*. 2004). Subsequent surveys were conducted for particular regions of the island or subpopulations of SI Hector's dolphins. In addition to covering different locations, these later studies involved a variety of analytical techniques and methods, including aerial surveys, genetic capture-recapture, and photo-ID mark-recapture (Table 2), which prevents a simple trend analysis of the abundance estimates for the subspecies as a whole. Recently, a second series of line-transect surveys has been completed for the South Island, resulting in a much larger abundance estimate of 14,849 SI Hector's dolphins (95% CI = 11,923 – 18,492). This abundance estimate was calculated as the sum of the averages of the summer and winter abundance estimates produced from the aerial surveys conducted along the south coast in 2010 (Clement *et al*. 2011), the north and east coasts in 2013 (Mackenzie and Clement 2014), and the west coast in 2014/2015 (Mackenzie and Clement 2016). Following some questions regarding the methods used to derive abundances estimates in these surveys, the abundance estimates were reviewed by an

Intercessional Expert Group (IEG) of the International Whaling Committee (IWC 2016). After an in-depth review, the IEG endorsed the abundance estimates but also made several recommendations to improve future work (IWC 2016). These surveys are discussed in more detail below.

The most recent aerial surveys of the west coast of the South Island (WCSI) were completed during summer 2014/2015 and winter 2015 and extended from Farewell Spit to Milford Sound (MacKenzie and Clement 2016). Unlike previous studies in this region, these surveys included substantial effort in waters beyond 4 nmi (7.4 km) from shore and included an "outer" survey zone between 12 nmi and 20 nmi from shore (22.2 – 37.0 km, MacKenzie and Clement 2016). Based on these surveys, summer and winter abundance estimates of 5,490 dolphins (95% CI = 3,319- 9,079) and 5,802 dolphins (95% CI = 3,879 – 8,679), respectively, were estimated using mark-recapture distance sampling after correcting for availability bias (or how "available" the dolphins are at or near the surface where they can be observed; Mackenzie and Clement 2016)). Despite the greater offshore extent of these surveys, the recent abundance estimates for the WCSI are very close to the estimate of 5,388 dolphins (95% CI = 3613 – 8034) produced from aerial surveys of the WCSI about fourteen years earlier by Slooten *et al.* (2004). The survey area in Slooten *et al.*'s (2004) study extended along the same area of coast, from Farewell Spit to Milford Sound, but only extended out to 10 nmi (18.5 km) offshore. While no sightings were made in the lower effort survey strata beyond 4 nmi (7.4 km) from shore in Slooten *et al.*'s (2004) study, Mackenzie and Clement (2016) observed 16 groups of dolphin in summer and 29 groups in winter beyond 4nmi (7.4 km) from shore. Mackenzie and Clement (2016) also observed some SI Hector's dolphins beyond 9.0 nmi (16.7 km) from shore and a few in waters as deep as 200 m.

The most recent surveys of the north (NCSI) and east coast (ECSI) of the South Island were conducted in the summer of 2012/2013 and winter 2013 and extended from Farewell Spit to Nugget Point and offshore to 20 nm (MacKenzie and Clement 2014). These aerial surveys produced an estimated summer abundance of 9,130 dolphins (95% CI= 7,001 – 13,517) and an estimated winter abundance of 7,456 dolphins (95% CI = 5,224 – 10,641, MacKenzie and Clement 2014). Later re-analysis of these survey data by Mackenzie and Clement (2016) updated these summer and winter abundance estimates to 9,728 (95% CI= 6,342 – 13,144) and 8,208 (95% CI =4,888 – 13,785), respectively. These estimates are substantially larger than the previous estimate of 1,880 dolphins (95% CI = 1384 – 2554) for these same regions based on small boat surveys between Farewell Spit and Long Point (Dawson *et al.* 2000, Clement *et al.* 2001, Du Fresne *et al.* 2001a, Dawson *et al.* 2004). Methods, analyses, survey years, and study areas differ between the earlier boat-based surveys and later aerial surveys, and although it is unclear what factor or factors are driving the large difference in the estimated abundance

between the studies, survey methodology and effort probably account for at least half of the difference. For example, 86% of the survey effort in the boat-based surveys occurred within 4 nmi of shore; the remainder of the survey effort was allocated to waters between 4 and 10 nmi from shore (Dawson *et al*. 2004). In contrast, the aerial surveys were stratified into three offshore zones – 0-4 nmi, 4-12 nmi, and 12-20 nmi – and although survey effort was higher in nearshore waters (0-4 nmi), almost half of the estimated summer abundance and three quarters of the estimated winter abundance occurred in waters beyond 4 nmi from shore (MacKenzie and Clement 2014). For several survey areas in particular (e.g., Pegasus Bay, Banks Peninsula, and Timaru), the most recent survey results suggested relatively high densities of SI Hectors' dolphins even within the outermost zone (12-20 nmi offshore, MacKenzie and Clement 2014). Thus, as noted by Mackenzie and Clement (2014), their offshore survey effort likely accounts for a portion of the discrepancy with previous, lower abundance estimates. However, other potential explanations cannot be ruled out at this stage and are needed to fully account for the fact that the estimated summer abundance of Hector's dolphins within 4 nmi of the coast in the 2012/2013 study (i.e., 4,500 dolphins) is about 2-2.5 times greater than the previous estimate (MacKenzie and Clement 2014).

Table 2. Various abundance estimates (N) for SI Hector's dolphins. General information regarding survey method and location are provided. Because methods vary among studies, results of the different studies are not directly comparable. Studies are organized by coastal region (WCSI = West Coast South Island, ECSI = East Coast South Island, NCSI = North Coast South Island, SCSI = South Coast South Island), and specific study areas within those coastal groupings are also noted.

Sampling Period	Survey Area	Research Method	N	95% Confidence Interval	Reference
2010-2015	**South Island** (to 20 nmi offshore)	Aerial line transects	14,849	11,923 – 18,492	MacKenzie & Clement 2016
1997-2000	**South Island** (to 10 nmi offshore)	Boat and aerial line transects	7,270	5,303-9,966	Slooten *et al.* 2004.; Dawson *et al.* 2004
1985	**South Island** (to 0.43 nmi offshore)	Boat, strip transects	3,274	N/A	Dawson & Slooten 1988
2014/2015	**WCSI** (Farewell Spit to Milford Sound)	Aerial line transects	5,490 (summer) 5,802 (winter)	3,319 – 9,079 3,879 – 8,679	MacKenzie & Clement 2016
2000-2001	**WCSI** (Farewell Spit to Milford Sound)	Aerial line transects	5,388	3,613 – 8,034	Slooten *et al.* 2004
2014-2015	**ECSI** (Kaikoura)	Genetic capture recapture	480	342-703	Hamner *et al.* 2016

2011-2012	**ECSI** (Cloudy Bay)	Genetic capture recapture	272	236 – 323	Hamner *et al.* 2013
2006-2009	**ECSI** (Cloudy and Clifford Bays)	Aerial line transects	951 (summer) 315 (winter) 188 (spring)	573- 1,577 173- 575 100- 355	DuFresne & Mattlin 2009
1989-1997	**ECSI** (Banks Peninsula)	Photo-ID, mark re-capture	1,119	744-1,682	Gormley *et al.* 2005
2012-2013	**ECSI & NCSI** (Farewell Spit to Nugget Point)	Re-analysis of Mackenzie & Clement 2014	9,728 (summer) 8,208 (winter)	7,001 – 13,517 4,888 – 13,785	MacKenzie & Clement 2016
2012-2013	**ECSI & NCSI** (Farewell Spit to Nugget Point)	Aerial line transects	9,130 (summer) 7,456 (winter)	6,342 – 13,144 5,224 – 10,641	MacKenzie & Clement 2014
1998/99	**ECSI & SCSI** (Motunau to Long Point) (Timaru to Long Point)	Boat line transect	1,597 399	1,175-2,171 279 - 570	(Du Fresne *et al.* 2001a)
1997-2000	**ECSI & NCSI & SCSI** (Farewell Spit to Long Point)	Boat line transect	1,880	1,246 – 2,843	Dawson *et al.* 2004
2010	**SCSI** (Puysegur to Nugget Point)	Re-analysis of Clement *et al.* 2011	238	113- 503	MacKenzie & Clement 2016
2010	**SCSI** (Puysegur to Nugget Point)	Aerial line transects	628	301- 1,311	Clement *et al.* 2011
2005/2006	**SCSI** (Te Waewae Bay)	Photo-ID mark-recapture	580 (summer) 380 (winter)	480-700 300-500	Rodda 2014
2004/2005	**SCSI** (Te Waewae Bay)	Photo-ID mark-recapture	403 (summer) 251 (autumn)	269-602 183-343	Green *et al.* 2007
1996- 1997	**SCSI** (Porpoise Bay)	Photo-ID mark-recapture	48	44-55	Bejder and Dawson 2001

The most recent surveys of the south coast of the South Island (SCSI) produced an initial abundance estimate of 628 dolphins (95% CI = 301 – 1,311, Clement *et al*. 2011). This abundance estimate was based on two aerial surveys completed in March and August 2010 from Puysegur Point to Nugget Point and extended out to the 100 m depth contour (Clement *et al.* 2011). Re-analysis of these survey data resulted in an estimate of 238 dolphins (95% CI = 113 – 503, MacKenzie and Clement 2016).

The first estimate of survival rates of SI Hector's dolphins was calculated using photo-identification data collected from 1984 to 1988 around Banks Peninsula (Slooten *et al.* 1992). Using two different methods to analyze the data, Slooten *et al.* (1992) calculated survival rates of 0.73 (SE= 0.065) to 0.85 (SE = 0.083) for dolphins over one year of age. Incorporating even the most optimistic of these survival rates into a Leslie-Matrix population model resulted in a decreasing population trend on the order of 5% per year, with an overall probability of population decline of 94% (Slooten and Lad 1991, Slooten *et al*. 1992). Evidence of a declining population and a growing awareness of the high level of gillnet-entanglement mortality of Hector's dolphins at Banks Peninsula, ultimately led to the establishment of the Marine Mammal Sanctuary around Banks Peninsula (BPMMS) in 1988 (Slooten and Lad 1991).

In the most recent analysis of the long-term photo-identification dataset, Gormley *et al*. (2012) compared survival rates for data collected during 1986 – 1988, prior to the designation of BPMMS, to rates for 1989 to 2006, after the designation, using a Bayesian random effects capture-recapture model. The mean annual survival rate was estimated as 0.863 (95% CI = 0.647 – 0.971) pre-sanctuary and 0.917 (95% CI = 0.802 – 0.984) post-sanctuary, which corresponds to a 90% probability of a 5.4% improvement in adult survival after the sanctuary was created (Gormley *et al*. 2012). Using a stage-structured matrix model and population simulations, Gormley *et al.* (2012) also estimated a mean annual population growth rate of 0.939 (95% CI = 0.779 – 1.025) pre-sanctuary and 0.995 (95% CI = 0.927 – 1.048) post-sanctuary, which corresponds to a 6% increase in population growth between the two time periods. Although these results indicate improved survival - possibly as a result of the sanctuary protections - the mean estimated annual population growth under post-sanctuary survival conditions still corresponds to a decrease of 0.5% per year, with only 41% of the population simulations resulting in a population increase (Gormley *et al*. 2012). (We note that, in 2008, after the time period analyzed by Gormley *et al.* (2012), the seaward boundary of BPMMS was extended from 4 nmi to 12 nmi from shore to provide increased protection of SI Hector's dolphins from seismic survey activities.)
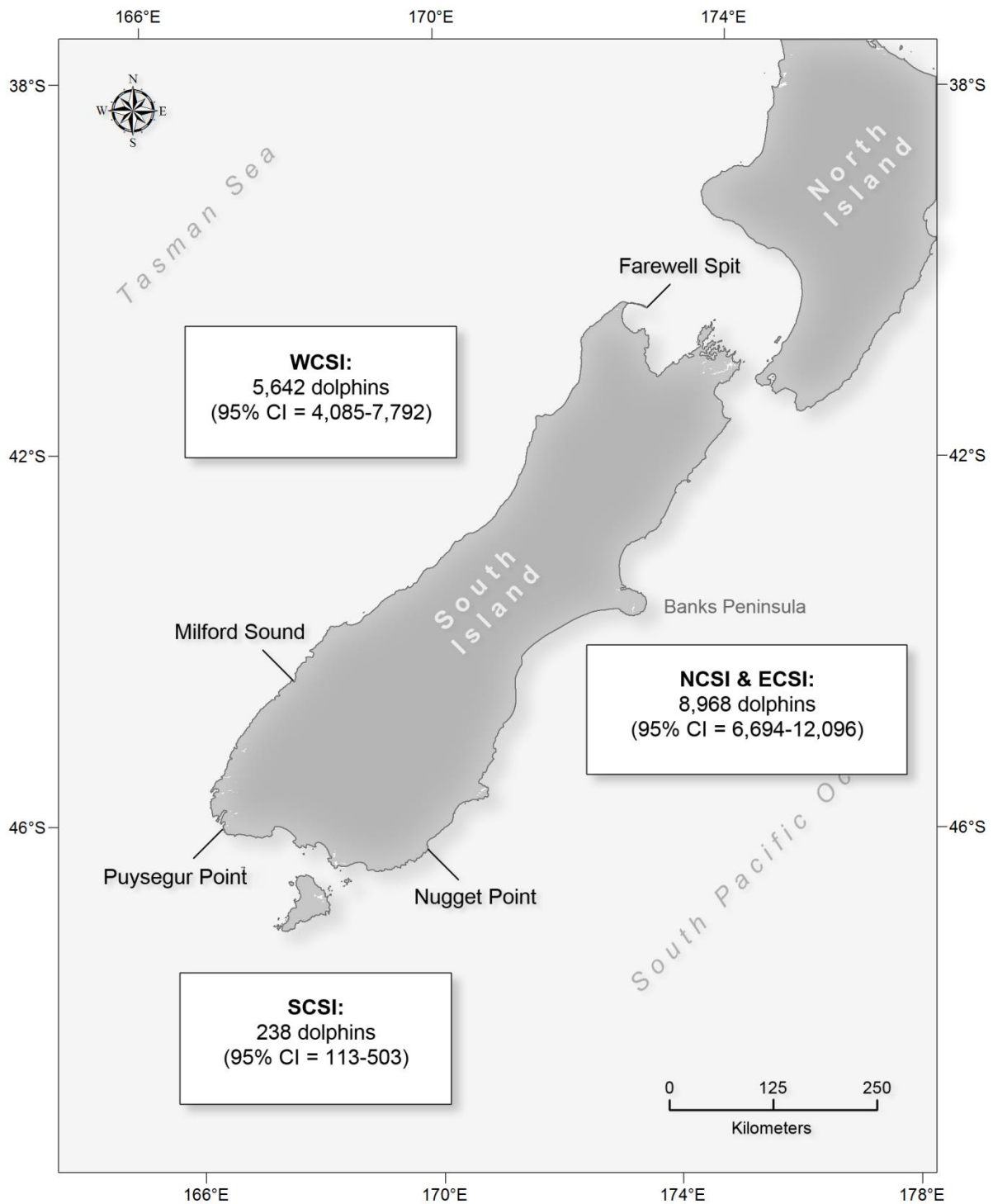
Figure 6. Survey regions and most recent abundance estimates from Mackenzie and Clement (2016) for SI Hector's dolphins.

In addition to the survival rates estimated for the local population of SI Hector's dolphins at Banks Peninsula, other modelling efforts have provided some insight into population trends. For example, Slooten and Davies (2012) conducted a review of the various risk assessments for Hector's dolphins that included a comparison of results of a stochastic Schaefer (1954) surplus production model (Slooten 2007a, Slooten and Dawson 2010) and a Bayesian model (Davies *et al.* 2008). The Schaefer model used abundance data collected for relevant areas around the South Island by Dawson *et al.* (2004) and Slooten *et al.* (2004) and entanglement estimates from an observer program for the central region of the ECSI (Baird and Bradford 2000). The Bayesian model used the same data to estimate biological and fishery-related parameters by fitting a Bayesian, age-structured, temporally and spatially stratified population model (Davies *et al*. 2008). Results of these two different modelling efforts suggested substantial declines in the population since 1970, following the expansion of the gillnet fishery, and both models predicted continued population declines over the next 50 years if current fisheries management practices continue (to 5,467 dolphins, Schaefer model; to 5,631 dolphins, Bayesian model; Slooten and Davies 2012). Evidence of a historical decline is also supported by the findings of Pichler and Baker (2000), who detected a significant decline in mtDNA diversity (from h = 0.65 to h = 0.35, p< 0.05) for ECSI Hector's dolphins in a comparison of contemporary (n=108) samples to historical samples (n=55) dating back to 1870 (see earlier discussion in section 2.3, Population Structure and Genetic Diversity).

3.0 THREATS

3.1 Approach to Assessing Threats

Section 4(a)(1) of the ESA requires the agency to determine whether a species is endangered or threatened because of any of the following factors (or threats):

1) destruction or modification of habitat;
2) overutilization for commercial, recreational, scientific, or educational purposes;
3) disease or predation;
4) inadequacy of existing regulatory mechanisms; or
5) other natural or human factors.

In this section of the report, we present information pertaining to each of these threat categories by subspecies. We discuss the severity or magnitude of each threat and whether it is a past (i.e., no longer occurring), present (i.e., occurring now), or future (i.e., something not yet occurring but is expected to occur in the future).

3.2 Threats to Maui's Dolphins

In August 2007, the New Zealand Department of Conservation (DOC) and the Ministry for Primary Industries (MPI, formerly called the Ministry of Fisheries or MFish) released a draft Threat Management Plan for Hector's dolphins. This plan describes the nature and level of actual and potential threats to Maui's dolphins as well as strategies to address those threats. Thus, this report and associated discussion documents were considered during our threats assessment.

In addition, in June 2012, DOC and MPI convened a risk assessment workshop to inform their review of the Maui's dolphin portion of the Threat Management Plan. The results of this semi-quantitative risk assessment are available in the report by Currey *et al*. (2012). The report identifies, evaluates, and rates threats to Maui's dolphins based on scoring by an expert panel. The report also includes estimates of the Potential Biological Removal (PBR), which is a management tool under the U.S. Marine Mammal Protection Act used to evaluate allowable levels of human-caused mortality (Wade 1998; Wade *et al*. 2012). (PBR is defined under section 3 of the Marine Mammal Protection Act as the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population (16 U.S.C. 1362).) Because this report is very comprehensive and recent, it greatly informed the assessment presented below. However, while the Currey *et al.* (2012) risk assessment was focused on threats expected to affect Maui's dolphins over the next 5 years, our review also considers past and potential future threats. In addition, we considered new information made available since the 2012 risk assessment was completed.

3.2.1 Destruction or Modification of Habitat

Threats to the habitat of Maui's dolphins include pollution, acoustic disturbance, mining, oil and gas development, and coastal development (Currey *et al*. 2012).

Persistent chemical pollutants are a concern for many cetacean species, which theoretically can accumulate high concentrations of contaminants due to their longevity, high trophic-level, and naturally high blubber content (Stockin *et al*. 2010). Contaminants are also specifically a concern for Hector's dolphins due to the dolphins' coastal distribution and thus close proximity to agricultural and industrial activities. Toxicological studies of contaminants, such as polychlorinated biphenyls (PCBs) and organochlorine (OC) pesticides, are limited for Maui's dolphins, and studies on emerging contaminants, such as brominated flame retardant (PBDEs) and perfluorinated chemicals, have yet to be done. Numerous studies on other cetacean species have linked contaminants, such as heavy metals, PCBs, and OC pesticides, with biological impacts, including endocrine disruption, reproductive impairment, immune suppression, and elevated infectious disease (e.g., Fujise *et al*. 1988, Kuiken *et al*. 1994, Jepson

et al. 2005, O'Hara and O'Shea 2001, Schwacke *et al*. 2002, Wells *et al*. 2005). Stockin *et al.* (2010) examined PCB and OC contaminant loads in stranded or entangled Hector's dolphins (n=27, SI Hector's dolphins; n=3, Maui's dolphins) sampled from 1997 to 2009. Results indicated high concentrations of these chemicals in both subspecies, and a roughly two-fold increase in levels of OC pesticides than had been previously reported for Hector's dolphins by Jones *et al*. (1999). However, as noted by Stockin *et al.* (2010), no PCB concentrations were above thresholds associated with reproductive and immunological effects (Stockin *et al.* 2010).

Interest in marine minerals mining along the North Island of New Zealand has been growing in recent years, with prospecting and exploration occurring mainly from Manukua Harbor south to New Plymouth (see Figure 7; Thompson 2012). Exploration activities have mainly targeted iron sands or titanomagnetite (Thompson 2012). Maui's dolphins occur within active and proposed exploration areas, which lie adjacent to and within the West Coast North Island Marine Mammal Sanctuary (WCNIMMS), which was established in 2008. Based on a search of the New Zealand Petroleum and Minerals' (NZP&M) map in May 2016 (http://data.nzpam.govt.nz/permitwebmaps?commodity=minerals), it appears that at least one prospecting permit and about four exploration permits have been issued for areas within or adjacent to the range of Maui's dolphin. (NZP&M is the government agency responsible for issuing mining permits for New Zealand's oil, gas and mineral resources.)

According to NZP&M, demand and exploration for petroleum (oil and gas) is also increasing, and the petroleum industry comprises a substantial part of New Zealand's economy. Based on a search in May 2016 of the NZP&M petroleum permit map (http://data.nzpam.govt.nz/permitwebmaps?commodity=petroleum), multiple areas within the sanctuary and the range of Mauis' dolphins are covered under existing exploration and mining permits. Large areas of the sanctuary are also covered under petroleum prospecting permits.

Mineral mining activities involving the large scale removal of sediment from the seabed are likely to lead to relatively long term (3-10 year) changes to benthic community composition, thereby altering prey availability and benthic topography (Thompson 2012). Other potential, unintended side-effects include the mobilization and accidental spilling of contaminants and exposure to greater levels of vessel traffic (Thompson 2012). Acoustic disturbance, such as from seismic surveys, sonar, and drilling activities, also poses a potential threat to Maui's dolphins, because it may have negative physical or physiological effects, such as shifts in hearing thresholds, and may disrupt normal behaviors, including navigating, migrating, and feeding (Gordon *et al.* 2003; Thompson 2012).

Plastic marine debris from both marine and land-based sources can accumulate in, and degrade, Maui's dolphins' habitat. Plastics and other synthetic, non-biodegradable materials in the marine environment create the potential for entanglement, injury, and ingestion. Although data are lacking to evaluate whether and the extent to which this threat is impacting Maui's dolphins, Currey *et al.* (2012) did identify plastics as being likely to affect population trends over the next 5 years. Plastic bags have been identified as a concern in particular, because they may be mistaken for squid, a typical prey item for Maui's dolphins.

The extent to which Maui's dolphins are currently being impacted by these and other habitat-related threats is assumed to be small. These threats have been characterized as having mainly sub-lethal effects, and combined, may currently be responsible for less than 4.5% of all Maui's dolphin mortalities (Currey *et al*. 2012). However, it is probable that Maui's dolphin habitat will become increasingly degraded as a result of pollution and acoustic and benthic disturbances due to increasing human pressure and demand for mineral and petroleum resources (MFish and DOC 2007b).

3.2.2 Overutilization

Overutilization of Maui's dolphins for commercial, recreational, scientific, or educational purposes does not appear to pose a significant threat to Maui's dolphin. Maui's dolphins have not been exploited commercially; although, Baker (1978, citing Abel *et al*. 1971) noted that, between 1969 and 1972, a few Hector's dolphins were taken for live exhibition at Marineland of New Zealand. It's not clear what subspecies was taken. Hector's dolphins have also apparently been taken for food, oil, and bait; however, the extent to which this occurred is unknown (Pichler *et al*. 2003). Unintentional capture ("bycatch") and mortality in commercial and recreational fisheries does pose a threat to Maui's dolphins and is discussed in detail under the threat category of "Inadequacy of Existing Regulatory Mechanisms" (section 3.2.4).

There is some evidence that commercial dolphin-watching vessels and swim-with-dolphin operations cause behavioral changes in Hector's dolphins (Bejder *et al*. 1999, Constantine 1999, Martinez *et al*. 2012). Such tourism activities, however, seem to occur at a relatively low intensity within the range of Maui's dolphins and instead are much more concentrated elsewhere - mainly the Bay of Islands and the Bay of Plenty on the east coast of the North Island and various locations of the South Island (Martinez 2010). Although tourism, and the potential related impacts of boat strike, noise, and displacement were identified as threats in the risk assessment completed by Currey *et al*. 2012, the expert panel did not think these threats were likely to affect population trends within the next 5 years.

3.2.3 Disease or Predation

Predation of Hector's dolphins by several shark species, such as seven-gill sharks (*Notorhynchus cepedianus)* and blue sharks (*Prionace glauca*), is known to occur; however, predation rates are not known (Slooten and Dawson 1988). Predation was not considered to be posing a threat to Maui's dolphins in the recent risk assessment by Currey *et al*. 2012.

Disease is another known source of mortality for Hector's dolphins. In their evaluation, Currey *et al.* (2012) categorized natural disease, stress-induced disease, and domestic animal vectors as posing threats that are likely to have population level effects on Maui's dolphins within the next 5 years. Prevalence of infectious disease and associated behavioral impacts and mortality rates have not been well studied in Hector's dolphins, so the significance of this source of mortality remains unclear. Recently, Roe *et al.* (2013) found that 7 of 28 Hector's dolphins (25%), including 2 of 3 Maui's dolphins, found beachcast between 2007 and 2011 and later necropsied had died as a result of *Toxoplasma gondii* infection. Of the 22 dolphins for which a definitive cause of death was established, a total of ten (45%) were found to have died due to infectious disease (*T. gondii* infections, bacterial infection, or fungal infection). These findings suggest that infectious disease is a significant source of mortality for Hector's dolphins, although the rates of disease in beachcast dolphins may not be representative of the population at large. In addition, while toxoplasmosis is typically a secondary disease in cetaceans, resulting in symptoms in immunosuppressed individuals rather than healthy individuals, there was no evidence of immunosuppression in these cases (Roe *et al.* 2013). This finding suggests that Hector's dolphins may be particularly susceptible to toxoplasmosis. Roe *et al.* (2013) also note that toxoplasmosis may have other effects beyond direct mortality and could be an important cause of neonatal loss. The source of the *T. gondii* infection could not be determined in this study, but exposure may be occurring through freshwater run-off from terrestrial sources (Roe *et al*. 2013).

3.2.4 Inadequacy of Existing Regulatory Mechanisms

3.2.4.1 Bycatch and Fisheries Management

Fishery-related mortality has been identified as posing a significant threat to Maui's dolphins. The Threat Management Plan for SI Hector's and Maui's dolphins identifies bycatch as the largest threat to Hector's dolphins (MFish and DOC 207b). The risk assessment completed by Currey *et al.* (2012) attributed 95.5% of the estimated human-caused mortalities forecasted to occur over the next 5 years to legal and illegal fishing-related activities. This translated into an estimated median of 4.97 Maui's dolphin mortalities (95% CI= 0.28 – 8.04) per year due to fishing activities.

Bycatch of Hector's dolphins occurs in both commercial and recreational fisheries and mainly in gillnet and trawl gear. Most of the quantitative data and published assessments of bycatch rates for Hector's dolphins to date have been for populations off the east coast of the South Island, and data on bycatch of Maui's dolphins are limited. Fishers are required to report any bycatch of Hector's dolphins, and the DOC also maintains a database of reports from the public of dead and stranded Hector's dolphins. Between 1921 and 2008, the DOC Incident Database contains 41 reports of dead Maui's dolphins, and cause of death was determinable for 11 dolphins. Of those 11 dolphins, five Maui's dolphins (45%) were found to have died due to "possible", "probable", or "known" entanglement (http://www.doc.govt.nz/our-work/hectors-and-maui-dolphin-incident-database/1921-2008/). Between July 2008 and January 2016, the DOC Incident Database lists an additional four confirmed Maui's dolphins, and of the two with determinable causes of death, one was an adult female found dead in January 2012 due to entanglement in a commercial net set (http://www.doc.govt.nz/our-work/hectors-and-maui-dolphin-incident-database/). (The other dolphin was found to have died due to natural causes.) The Threat Management Plan notes that entanglements may be under-reported, because although fishers are required by law to report any entanglements, there is no incentive to do so (MFish and DOC 207b; see also discussion in Slooten 2007b). For example, the National Institute of Water and Atmospheric Research (NIWA) estimated that during the years 2000 – 2006 there were 110 – 150 Hector's and Maui's dolphin mortalities in fishing gear per year – i.e. a total of 770 – 1,050 Hector's and Maui's dolphin mortalities over that time period (Davies et al. 2008). Of these, 48 were reported (Slooten and Dawson 2016).

While trawl gear is a known risk to SI Hector's dolphins, there are apparently no reports of Maui's dolphins being caught in trawls (MFish and DOC 2007b). However, this may not be accurate: Bird and Palka (2013) report that, in interviews conducted by MFish, fishermen have reported captures of Maui's dolphins in trawls off the west coast of the North Island. Regardless, the potential for bycatch of Maui's dolphins in trawls is a concern, because other dolphin species have been reported as bycatch in trawls operating off the west coast of the North Island and trawling does occur within a large portion of the Maui's dolphin range. Data to fully evaluate the risk of bycatch and mortality rate due to bycatch in trawls are lacking as observer coverage of the trawl fishery has been very low (MFish and DOC 2007b, Slooten and Dawson 2016) and has only recently expanded following a review of the Threat Management Plan in 2013.

Management of fisheries impacts to Maui's dolphins is legislated under the Fisheries Act of 1996 and the Marine Mammals Protection Act of 1978, and responsibility for protecting Maui's dolphins is shared by the MPI (formerly, MFish) and the DOC. Measures to reduce bycatch and

other threats to Maui's dolphins have been implemented along the West coast of the North Island under both laws (see Figure 7).

Although commercial gillnetting had been practiced in New Zealand since 1930 (DOC and MFish 1994), fishing effort was low until the mid-1970s (Dawson 1991). Eventually, by the 1980s, bycatch of dolphins in gillnets became a serious concern in New Zealand (Dawson and Slooten 2005). In 1988, the first protected area for Hector's dolphins was established around Banks Peninsula in the South Island. Eventually, in 2003, MFish began to address bycatch of Maui's dolphins by closing waters to set netting from Maunganui Bluff to Pariokariwa Point out to 4 nmi and inside the entrance to the Manukau Harbor (Figure 7). Trawling was also prohibited out to 2nmi along most of the coastline within the sanctuary and out to 4 nmi within a short portion of the Maui's dolphin's core range (Figure 7). Commercial and recreational gillnetting continued within harbors and in the southern portion of the Maui's dolphin range.

In 2007, when the draft Threat Management Plan was released, the MPI and DOC concluded that bycatch was still the most serious threat to Hector's dolphins. In 2008, MFish expanded protection for Maui's dolphins by extending the set netting closure out to 7 nmi (instead of 4 nmi) and farther into Manukau Harbor. Following judicial review, the decision to extend the closure out to 7 nmi was remanded back to MPI for reconsideration but was ultimately upheld in 2011. Then, in 2012, following an entanglement of a Maui's dolphin off Cape Egmont, an interim set netting ban was put in place for waters from Pariokariwa Point to Hawera (Figure 8; *Gazette*, 28 June 2012). These interim measures were supported by the risk assessment completed by Currey *et al.* (2012), which had concluded that incidental take in set net fisheries in northern Taranaki was one of the three greatest areas of concern for Maui's dolphins. Also in response to the 2012 entanglement off Cape Egmont, the DOC Minister expanded the marine mammal sanctuary by 350 square kilometers to prohibit commercial and recreational set net fishing between two and seven nautical miles offshore between Pariokariwa Point and the Waiwhakaiho River, Taranaki under the Marine Mammals Protection Act 1978 (Figure 7). In 2013, the MPI determined that their interim measures would be made permanent (MPI and DOC 2013).
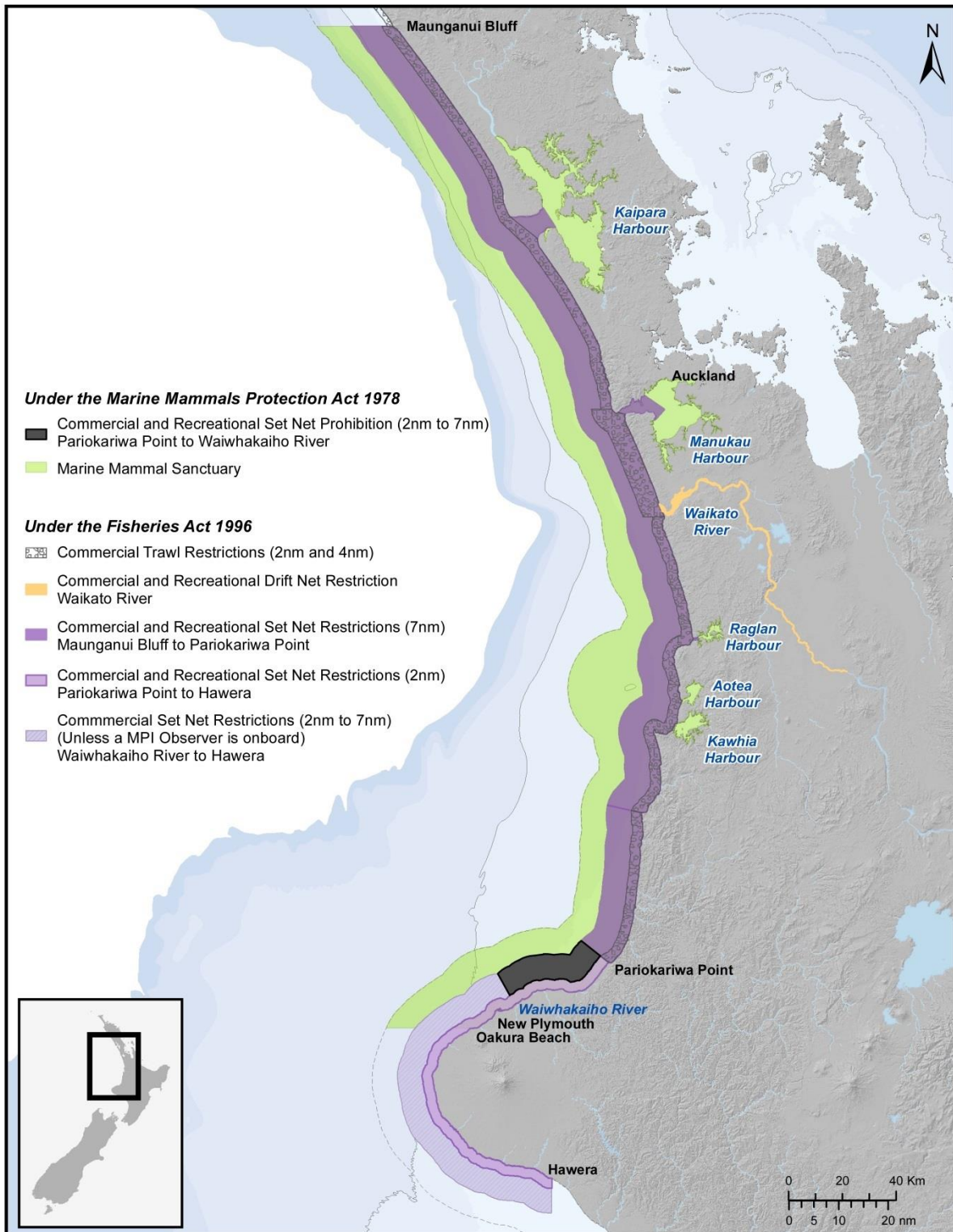
Figure 7. Protective measures in place for Maui's dolphins (Downloaded on May 25, 2016, from: http://www.doc.govt.nz/our-work/our-work-with-maui-dolphin/review-of-the-mauis-dolphin-threat-management-plan/). Maui's dolphins range from around Maunganui Bluff to slightly south of Hawera.
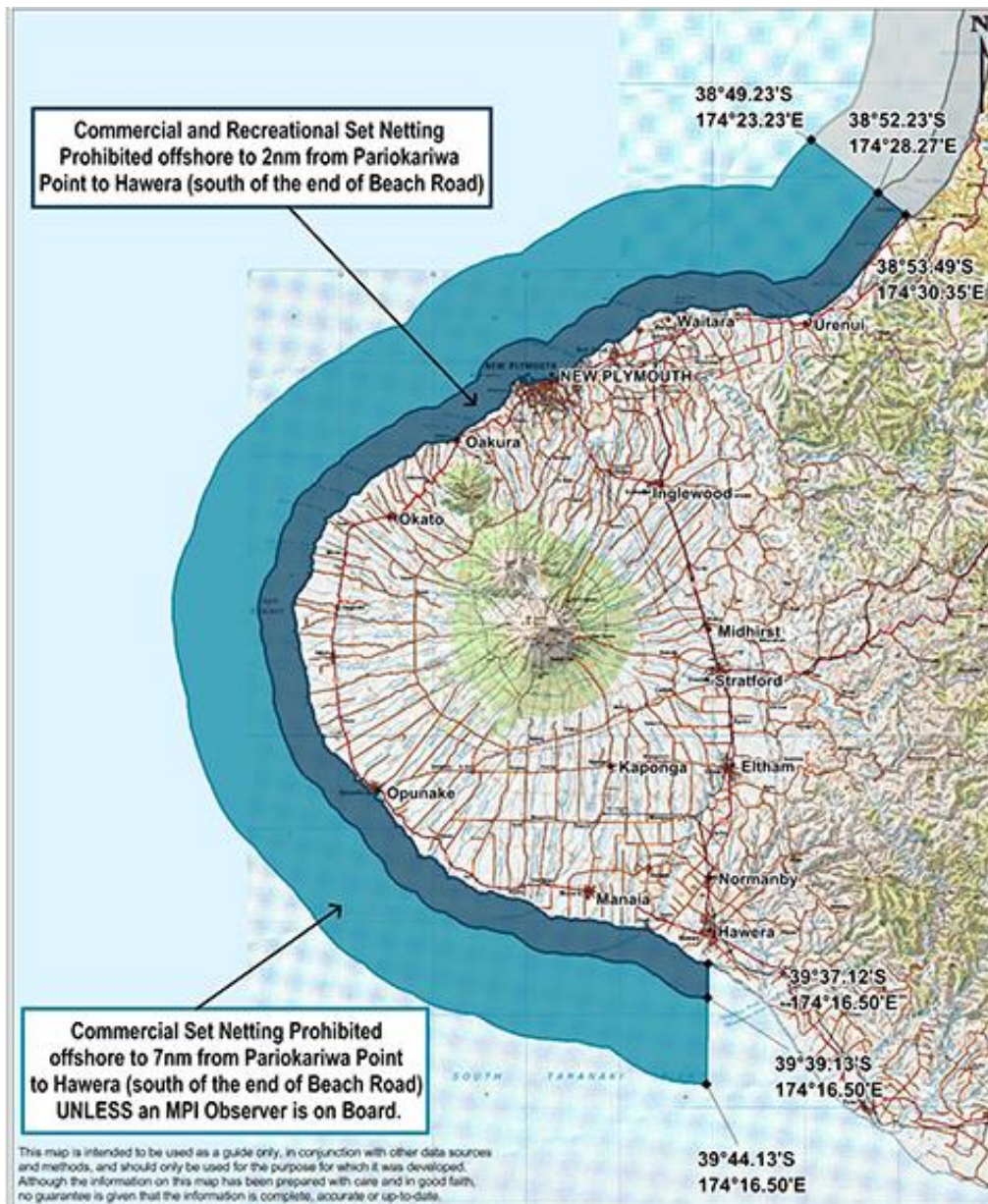
Figure 8. Interim set net restrictions put in place in 2012 following an entanglement of a Maui's dolphin off Cape Egmont, south of the protected areas. (Map downloaded from http://www.mpi.govt.nz/news-and-resources/consultations/interim-set-net-measures-to-protect-mauis-dolphins/.)

Additional management measures adopted in 2013 include: mandatory use of fishery observers for set netting in non-restricted areas of the Taranaki coastline, improving data on Maui's dolphin distribution and set net activity within harbors, and monitoring commercial trawlers operating between two and seven nautical miles offshore from Maunganui Bluff to Pariokariwa

Point. In 2013, the regulations were also amended to allow commercial ring netting within the closed area within Manukau Harbor, given specific restrictions on the length and height of ring nets, and time and duration of deployment.

The steady expansion of area-based, bycatch-reduction measures along the west coast of the North Island has resulted in a substantial level of protection for Maui's dolphins. However, bycatch remains a concern for Maui's dolphins, because current fisheries restrictions do not extend throughout their range and certain forms of fishing still occur within the core portion of the subspecies' range (Figure 7). In particular, commercial and non-commercial set netting occur within all west coast harbors, with all areas within the harbors, from intertidal areas to the deeper channels, being fished for species like flounder, mullet, and rig (MFish and DOC 2007b). Sightings data (Figure 2a; Slooten *et al*. 2005) and passive acoustic data (Rayment *et al*. 2011a) indicate that Maui's dolphins occur at least occasionally within west coast harbors and therefore may be at risk of entanglement in these areas (MFish and DOC 2007b). In addition, the southern extension of the gillnetting prohibitions that was put in place in 2012 only extends out to 2 nmi from shore, as opposed to the 7 nmi boundary elsewhere along the west coast. Beyond the 2 nmi, gillnetting is permitted in this portion of the range if an MPI observer is on board (Figure 8). Furthermore, the extension of the closed area in the southern portion of the dolphin's range may not extend far enough. The risk assessment of Currey *et al*. (2012) used survey and non-survey sightings data to develop a distribution for Maui's dolphins that extends to Whanganui, which is about 70 km south of the current gillnet closed area boundary at Hawera. Trawling also continues in waters past the existing 2 nmi or 4 nmi offshore boundary for the trawling closed area – even in the core portion of the Maui's dolphin's range (Figure 7). Currey *et al.* (2012) concluded trawling in this zone was a source of continued bycatch risk for Maui's dolphins. The current level of bycatch is estimated at 3.28 – 4.16 Maui's dolphin mortalities per year (Slooten 2014). Before the protected area extensions in 2012 and 2013, estimated bycatch was about 75 times the PBR of 0.044-0.1 Maui's dolphins per year (Wade *et al*. 2012). It is currently >54 times the PBR (Slooten 2014).

The MPI has established a hotline for reporting violations of fishing restrictions, and DOC maintains a database for all reports of stranded, entangled, and dead Hector's dolphins. However, there are no data available to evaluate the level of compliance with the existing regulations, nor are there data available regarding the level of monitoring and enforcement.

The DOC has investigated the use of pingers or acoustic deterrents to reduce bycatch of Hector's dolphins. Efficacy of pingers in reducing bycatch of Hector's dolphins, however, has not yet been clearly established (Stone *et al*. 2000b, Dawson 1998), and their use is not required in the North Island fisheries.

3.2.4.2 Mining and Acoustic Impacts

The West Coast North Island Marine Mammal Sanctuary (WCNIMMS) was established in 2008 as part of the Hector's and Maui's dolphin Threat Management Plan, and restrictions were put in place on seabed mining and acoustic seismic surveys within the sanctuary. In particular, seabed mineral mining was prohibited out to 2 nmi along the full length of the sanctuary and out to 4 nmi south of Raglan Harbor to north of Manakau Harbour (Figure 9). A large swath of the sanctuary, which extends out 12 nmi from the coast, thus remains open to mining (Figure 9). Requirements for seismic surveying include mandatory notification prior to conducting surveys and mandatory reporting of any interactions with dolphins. Qualified marine mammal observers are required on all survey ships to help ensure that no whales or dolphins are too close to the ship. When visibility is poor, hydrophones must be used to listen for whale and dolphin sounds (*Gazette*, 25 September 2008). Other operational requirements were also specified (Gazette: *Gazette*, 25 September 2008). In August, 2012, with input from stakeholders and other interested parties, the DOC Minister and the Minister of Energy and Resources developed a voluntary "Code of Conduct for Minimizing Acoustic Disturbance to Marine Mammals from Seismic Surveys Operations." This voluntary guidance was intended to increase protections for Mau's dolphins, in part by identifying their entire historical range out to 100m water depth as an "Area of Ecological Significance," which triggers additional mitigation requirements. Shortly thereafter, in November 2013, the DOC and MPI announced a decision to formally regulate seismic surveying making the 2012 code of conduct a mandatory standard. The mandatory code of conduct applies to Territorial waters, the Exclusive Economic Zone (EEZ) of New Zealand, and within all marine mammal sanctuaries, and it continues to include requirements for planning, operations, monitoring, and reporting. The 2013 code of conduct is currently undergoing review and may be further augmented to increase protections for Maui's dolphins and other species of concern.

3.2.4.3 Additional Protections under the Marine Mammals Protection Act of 1978

Maui's dolphins are afforded protection under New Zealand's Marine Mammals Protection Act (NZ MMPA), which as with the U.S. Marine Mammal Protection Act of 1972, applies to all marine mammals. Under the NZ MMPA, permits must be issued to authorize any "take" of Hector's dolphins. ("Take" being defined as actions that harm, harass, injure, or attract.) The NZ MMPA also authorizes the DOC to establish marine mammal sanctuaries, and it provides for the development of Population Management Plans (PMPs). These plans set maximum allowable levels of fishery-related mortality (MMPA 1978 section 3F); and for "threatened species," the target mortality levels must be set such that they allow the particular species to recover as quickly as possible and within fewer than 20 years (MMPA 1978, section 3F(a)). Hector's dolphins were declared a "threatened" species in 1999, and Maui's dolphin has been ranked as "nationally critical" - the highest risk category in the New Zealand Threat Classification system
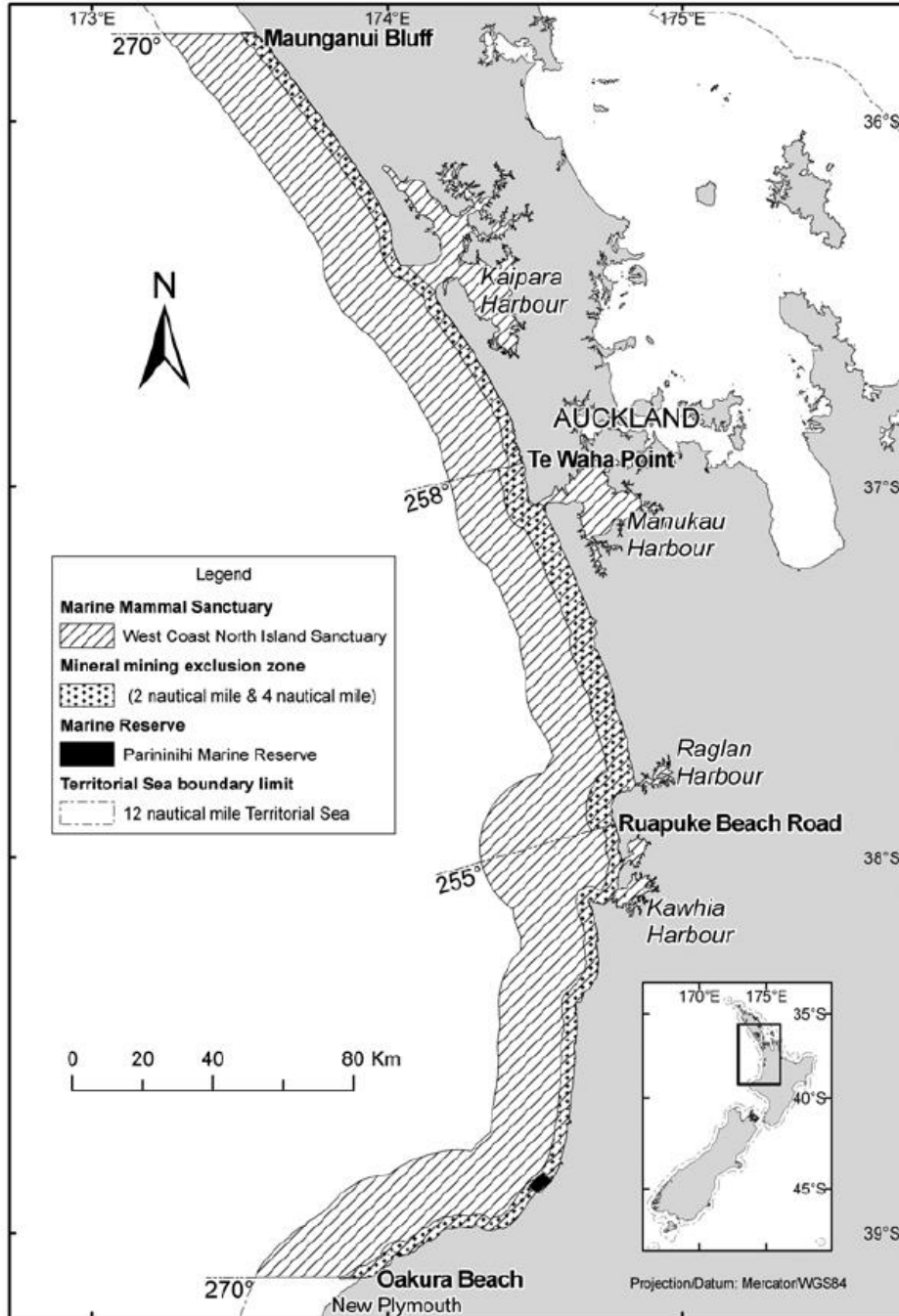
Figure 9. Mineral mining exclusion zones within the WCNI MMS.
(Source: http://www.doc.govt.nz/wcni)

(Baker *et al*. 2010). However, a PMP has not yet been developed for Maui's dolphins, and thus no maximum allowable level of fishery-related mortality has been established. Although New Zealand's general policy is that threatened species should be recovered to achieve a non-threatened status, in the absence of a PMP there is no obligation to require such a recovery

(MFish and DOC 2007b). In the absence of a PMP, the MPI can, after consultation with the DOC, implement measures to avoid, remedy, or mitigate the effect of fishing related mortality on Maui's dolphins (MFish and DOC 2007b); such existing measures were discussed above. Also, as already noted, the MPI and DOC have developed a Threat Management Plan for Hector's dolphins; however, this is a non-regulatory plan that serves to outline management strategies to minimize and mitigate threats to Hector's dolphins, and has mainly focused on fisheries threats to date.

3.2.4.4 Summary

As indicated in the discussion above, there are gaps in the current regulatory protections for Maui's dolphins. In particular, there is continued risk of fisheries interactions and bycatch, acoustic disturbance, and disease. Thus, while the protections for Maui's dolphins have gradually increased from 2003 to present, there is insufficient evidence to conclude these measures are adequate in terms of minimizing threats such that the subspecies can recover. Population viability analyses performed under previous management scenarios predicted continued declines in abundance of Maui's dolphins or failure to recover (Burkhart and Slooten 2003, Slooten 2007a), as do more recent analyses under the current fisheries management regime (Slooten 2013, 2014,2015). More recent modelling work does indicate that recovery of this subspecies will only occur under circumstances where human-induced mortality is extremely minimal (Slooten 2013, 2014, 2015; Hamner *et al.*, 2014b). The recent risk assessment by Currey *et al*. 2012 estimated that the mortality rate due to all human-caused threats - about 95% of which are due to fisheries interactions - is 75.5 times (95% CI: 12.4– 150.7) higher than the level of PBR, which is one dolphin mortality every 10 to 23 years (Hamner *et al.*, 2014b). The recent extensions to the protection measures have reduced bycatch to 3.28 – 4.16 Maui's dolphin mortalities per year or >54 times the PBR (Slooten 2014).

3.2.5 Other Natural or Human Factors

Other threats identified in the 2012 risk assessment and characterized as being likely to affect population trends within the next 5 years include fishing vessel noise, disturbance, and trophic effects of fishing; however, these threats were considered to collectively make very limited contributions to the overall level of human-caused mortality (Currey *et al*. 2012). Although vessel traffic and its associated impacts of disturbance and boat strikes were considered to contribute little to annual mortality of Maui's dolphins, mortality due to vessel traffic was rated as having a 47.8% chance of exceeding PBR (Table 3, Currey *et al.* 2012). Due to their coastal distribution and apparent attraction to small boats (Baker 1978, Slooten and Dawson 1988), the potential for boat strikes could be considered relatively high, but reports of boat strikes have been extremely rare (Stone and Yoshinaga 2000a). One of the few documented boat strikes involved two SI Hector's dolphin calves. In 1999, two calves, both estimated to be younger

than 4 weeks old, were recovered on successive days from Akaroa Harbor, and autopsy results confirmed that cause of death for one calf was collision with a boat and for the other calf, a propeller strike (Stone and Yoshinaga 2000a). None of the reports within the DOC Incident Database from July 2008 to April 2016 are listed with boat strike as cause of death.

Table 3. Analysis of threat categories as presented in Currey *et al.* (2012). Estimated mortality was based on an average of the nine-member expert panel's opinion on the expected mortality (including upper and lower bounds) for each threat that had been identified as being likely to affect the subspecies over the next five years. The risk ratio is the level of estimated population mortality as a proportion of the PBR, which was estimated to be 1 dolphin every 10 to 23 years (Hamner *et al.* 2014b).

THREAT CLASS	ESTIMATED MORTALITIES			RISK RATIO			LIKLIHOOD OF EXCEEDING PBR
	MEDIAN	95% CI LOWER	95% CI UPPER	MEDIAN	95% CI LOWER	95% CI UPPER	MEDIAN PERCENTAGE
Fishing	4.97	0.28	8.04	71.5	3.7	143.6	100.0
Mining and oil activities	0.10	0.01	0.46	1.5	0.1	7.4	61.3
Vessel traffic	0.07	<0.01	0.19	1.0	0.1	3.1	47.8
Pollution	0.05	<0.01	0.36	0.8	<0.1	5.9	40.2
Disease	<0.01	<0.01	0.36	<0.1	<0.1	5.5	29.5
Total	**5.27**	**0.97**	**8.39**	**75.5**	**12.4**	**150.7**	**100.0**

3.3 Threats to SI Hector's Dolphins

3.3.1 Destruction or Modification of Habitat

Due to their coastal distribution, SI Hector's dolphins are at elevated risk for exposure to a variety of contaminants and pollutants, including heavy metals, organochlorines, oils spills, and plastic debris (MFish and DOC 2007b). As discussed earlier for Maui's dolphins, persistent chemical pollutants are a concern for SI Hector's dolphins, which can theoretically accumulate high concentrations of contaminants due to their longevity, high trophic-level, and naturally high blubber content (Stockin *et al.* 2010). In cetaceans, biological impacts resulting from accumulation of contaminants such as heavy metals, PCBs, and organochlorine (OC) pesticides include endocrine disruption, reproductive impairment, immune suppression, and elevated infectious disease (e.g., Fujise *et al.* 1988, Kuiken *et al.* 1994, O'Hara and O'Shea 2001, Schwacke *et al.* 2002, Jepson *et al.* 2005, Wells *et al.* 2005). As previously mentioned, Stockin *et al.* (2010) examined PCB and OC contaminant loads in stranded or entangled Hector's dolphins (n=27, SI Hector's dolphins; n=3, Maui's dolphins) sampled from 1997 to 2009. Results indicated high concentrations of these chemicals in both subspecies, and a roughly two-fold increase in

levels of OC pesticides than had been previously reported for Hector's dolphins by Jones *et al*. (1999). However, no PCB concentrations were above thresholds associated with reproductive and immunological effects (Stockin *et al.* 2010). High levels of polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs), which are two related and ubiquitous chemical contaminants, were also found to occur at unexpected levels in the blubber of 6 SI Hector's dolphins (Buckland *et al*. 1990).

Data on heavy metal accumulation and effects in Hector's dolphins is extremely limited. Hector's dolphins, like other cetaceans, have been found to bioaccumulate certain metals to various levels. Relatively high cadmium levels (0.01-7.53 ppm) have been detected in Hector's dolphins (Slooten and Dawson 1994). The cause of these high cadmium levels has not been established.

Plastic marine debris from both marine and land-based sources can accumulate in and degrade Hector's dolphins' habitat. Plastics and other synthetic, non-biodegradable materials in the marine environment create the potential for entanglement, injury, and ingestion by various marine species. As with other marine mammals, Hector's dolphins may become entangled and subsequently wounded, or have impaired foraging ability, and/or increased susceptibility to predation. Ingestion of plastics by marine species has been associated with a multitude of impacts including blockage of the digestive tract, starvation, reduction in reproductive capacity, drowning, and possible accumulation of toxic compounds (Laist 1997, Gregory 2009). Plastic debris was found in the stomach of a SI Hector's dolphin that stranded along the coast of the Canterbury region, and there are anecdotal reports of SI Hector's dolphins off Banks Peninsula with fishing line or netting entangling the head or upper body and cutting into the blubber (MFish and DOC 2007b).

Mining occurs along the west coast of the South Island where there are significant nearshore and beach deposits of ilmenite (mined mainly for titanium dioxide). The Threat Management Plan for Hector's dolphins identified possible impacts of mining activity, including loss or reduction in prey species, noise, and vessel disturbance (MFish and DOC 2007b). Based on a search of the New Zealand Petroleum and Minerals' (NZP&M) map in June 2016 (http://data.nzpam.govt.nz/permitwebmaps?commodity=minerals), a large portion of the SI Hector's dolphin west coast range is included in a prospecting permit application, indicating the likelihood of continued mining activity in this region.

Demand and exploration for petroleum is increasing in New Zealand, and large areas along the south eastern coast of the South Island are covered by prospecting permits (http://data.nzpam.govt.nz/permitwebmaps?commodity=petroleum, June 2016). Drill ships

are also operated off Canterbury and along the west coast of the South Island. Potential habitat impacts include oil spills; increased vessel traffic; and acoustic disturbances from seismic surveys, sonar, and drilling activities. Contaminants in oil and gas may impact the health of the dolphins, and the associated noise may disrupt normal behaviors, such as navigating, migrating, and feeding (Gordon *et al.* 2003, Thompson 2012).

Alteration and degradation of the SI Hector's dolphins' habitat is occurring as a result of multiple forms of pollution and mining activities. Existing data clearly indicate that SI Hector's dolphins are exposed to multiple habitat-related threats. However, the extent to which Hector's dolphins are being impacted - both individually and at a population level – by these habitat-related threats is not yet established due to insufficient data (MFish and DOC 2007b). It is possible that Hector's dolphin habitat will become increasingly degraded in the future with increasing human use of the coastal zone and its resources (MFish and DOC 2007b).

3.3.2 Overutilization
Hector's dolphins have not been systematically captured for any commercial, recreational, scientific or educational purposes; although, as noted earlier, a few Hector's dolphins have been taken for live exhibition. While Hector's dolphins have also apparently been taken for food, oil, and bait, the extent to which this occurred is not known (Pichler *et al*. 2003). As with Maui's dolphins, unintentional capture ("bycatch") and mortality in commercial and recreational fisheries does pose a threat to SI Hector's dolphins and is discussed in detail under the threat category of "Inadequacy of Existing Regulatory Mechanisms" (section 3.3.4).

Marine mammal viewing and 'swim-with' activities are increasingly popular tourist activities in New Zealand, and there is growing evidence that commercial dolphin-watching vessels and swim-with-dolphin operations cause behavioral changes in Hector's dolphins (Bejder *et al*. 1999, Constantine 1999, Martinez *et al*. 2012). At the time the Threat Management Plan was drafted, about 20 permits had been issued to specifically authorize viewing and/or swimming with Hector's dolphins by a commercial operation. The majority of commercial viewing and encounter operations occur on the South Island and are especially popular off Kaikoura and within Akaroa Harbor (Figure 1 and 2c), which have become major eco-tourist destinations in New Zealand (Martinez 2010). Within Akaroa Harbor, and as of 2010, there were up to about 18 daily 'swim-with' trips and 14 dolphin-watching trips per day between November and March that specifically target Hector's dolphins (Martinez 2010). In addition to permitted commercial operations, opportunistic viewing also occurs by both commercial and recreational boaters.

In a study of SI Hector's dolphins in Porpoise Bay, Bejder *et al.* (1999) found that while SI Hector's dolphins were not displaced by dolphin-watching tour boats, the dolphins did respond

by approaching the boats, especially initially, and by forming significantly tighter groupings. A possible interpretation of the behavioral response of 'bunching' is that the boat is perceived as some kind of threat and may in fact cause the animals some level of stress (Constantine 1999). In Akaroa Harbor, where tourism activity is relatively high, Martinez (2010) found that both diving (which is considered a feeding behavior) and travelling were significantly disrupted by vessel interactions. Evidence also indicates that the use of sounds to attract Hector's dolphins to swimmers affects the behavior of the dolphins (Martinez *et al.* 2012). For example, both the number and the duration of close approaches by Hector's dolphins were significantly greater when a swimmer banged two rocks together underwater (Martinez *et al.* 2012). Such deliberate efforts to attract Hector's dolphins may have behavioral consequences such as disrupted or reduced foraging time, which in turn can have biological consequences (Martinez *et al*. 2012). Based on the coastal photo-ID surveys conducted around Banks Peninsula between 1985 and 2006, Rayment *et al.* (2009a) found that 80% of the dolphins had alongshore home ranges that included Akaroa Harbor, and for half of these dolphins, Akaroa Harbor served as a core use or "hub" area. This finding indicates that a relatively large portion of the regional SI Hector's dolphin population is exposed to the high level of tourist activity in Akaroa Harbor (Rayment *et al*. 2009a).

Overall, the available data indicate there are short-term changes in the behavior of SI Hector's dolphins in response to tourism activities. Short-term behavioral changes for SI Hectors' dolphins include altered direction of travel and reduced feeding opportunities. The longer-term impacts on SI Hector's dolphins are not yet clear but could include physiological stress, reduced energy intake, and possibly even reduced calving success. Linkages between immediate behavioral responses to vessel traffic and longer-term biological consequences have been established for other species (e.g., *Tursiops* sp.) and include declines in abundance and reduced reproductive success in females (Bejder *et al*. 2006a, 2006b, 2006c). Given these findings and the fact that dolphin-watching operations occur in multiple areas of their range (e.g., Porpoise Bay, Timaru, Akaroa Harbor, and Marlborough Sounds), dolphin-watching and 'swim-with' activities are likely posing a sub-lethal threat to this subspecies. The magnitude of this threat cannot yet be established, but this threat is likely to persist given the popularity and lucrativeness of the eco-tourism industry of New Zealand.

3.3.3 Disease or Predation
As previously mentioned, predation of Hector's dolphins by several shark species, such as broadnose seven-gill sharks (*Notorhynchus cepedianus)* and blue sharks (*Prionace glauca*), is known to occur (Slooten and Dawson 1988). Although seven-gill sharks are particularly common around Banks Peninsula, predation rates are not known (Slooten and Dawson 1988), and there is no evidence to suggest predation is posing a threat to this subspecies.

Disease is another source of mortality for Hector's dolphins; however, prevalence of infectious disease and associated impacts have not yet been well studied in Hector's dolphins. Recently, Roe *et al.* (2013) found that 5 of 25 SI Hectors' dolphins (20%) collected from the beach between 2007 and 2011 died as a result of *Toxoplasma gondii* infection. Fifteen of the 25 dolphins necropsied (60%) were positive for *T. gondii* (Roe *et al*. 2013), indicating a high rate of infection. Of the 22 dolphins for which a definitive cause of death was established, a total of ten (45%) were found to have died due to infectious disease (*T. gondii* infections, bacterial infection, or fungal infection).
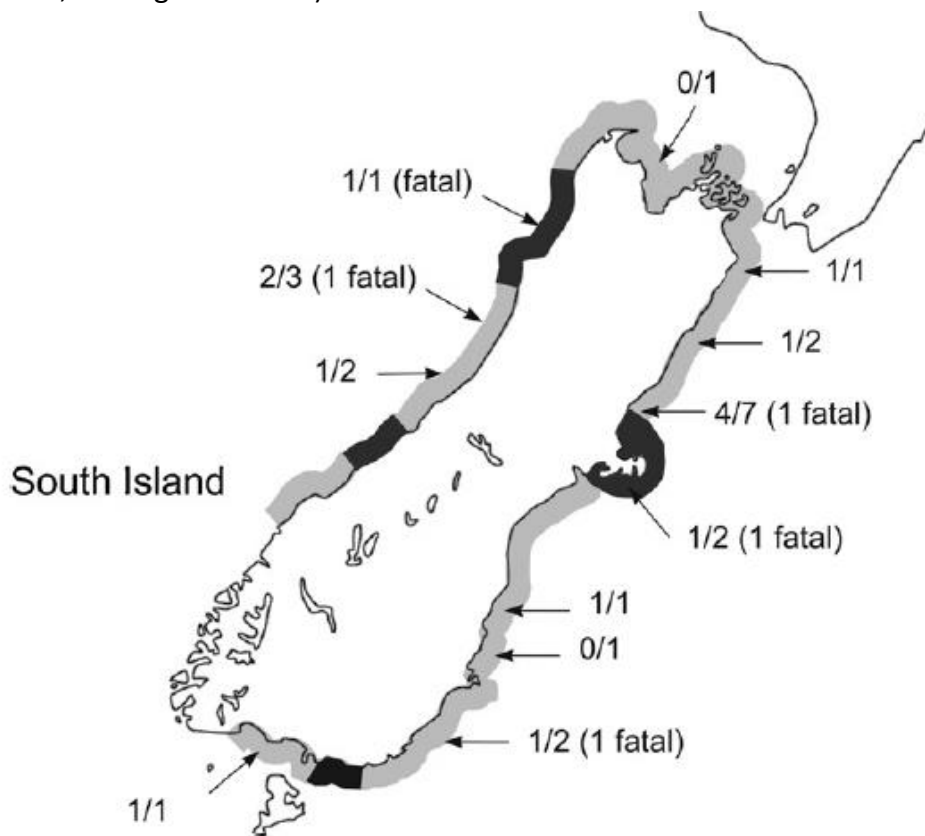

Figure 10. Location of individual stranded dolphins (arrows), with number of total dolphins collected at that site as the denominator and number testing positive for *T. gondii* as the numerator. Fatal cases of toxoplasmosis are also noted. Shaded coastal areas indicate SI Hector's dolphins range, and darker shaded regions representing areas with highest population density. (No location was recorded for one *T. gondii* -positive dolphin.) (Figure taken from Roe *et al*. 2013).

These findings suggest that infectious disease is common in SI Hector's dolphins and may be a significant source of mortality. In addition, while toxoplasmosis is typically a secondary disease in cetaceans, resulting in symptoms in immunosuppressed individuals rather than healthy individuals, there was no evidence of immunosuppression in these cases, suggesting that Hector's dolphins could be particularly susceptible to toxoplasmosis (Roe *et al*. 2013). Beyond

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direct mortality, toxoplasmosis can also have other biological consequences, such as behavioral changes, reduced reproductive rate, and neonatal loss. The source of the *T. gondii* infection could not be determined in this study, but exposure may be occurring through freshwater run-off from terrestrial sources (Roe *et al*. 2013). Based on the distribution of the fatal cases of *T. gondii* infection, which occurred throughout almost the entire range of the SI Hector's dolphin (Figure 10), exposure is probably occurring over broad areas. Overall, the available data for SI Hector's dolphins suggest that disease, especially toxoplasmosis, may be posing a threat to this subspecies throughout its range. Because stranded animals may not be a representative sample of the live population, additional research is needed to determine the prevalence of infectious disease in SI Hector's dolphins and fully evaluate this potential threat.

3.3.4 Inadequacy of Existing Regulatory Mechanisms

3.3.4.1 Bycatch and Fisheries Management

By the 1980s, bycatch of dolphin species in gillnets was recognized as a serious issue in New Zealand (Dawson and Slooten 2005). In the South Island, a region of particular concern for Hector's dolphins is the Pegasus Bay and Canterbury Bight area along the east coast, where there has been a high degree of overlap between inshore gillnetting and a locally abundant population of SI Hector's dolphins. Commercial gillnetting here primarily targets rig *(Mustelus lenticulatus)*, elephant fish (*Callorhynchus milli*)), school shark (*Galeorhinus australis),* and moki *(Latridopsis ciliaris),* and following implementation in 1986 of the Individual Transferable Quota system in New Zealand, other species, including spiny dogfish *(Squalus acanthias),* kahawai *(Arripis trutta),* and ling *(Genypterus blacodes)* are also targeted. Recreational gillnetting occurs mainly in shallow water for flounder (*Rhombosolea* spp.) or for reef fish, such as moki and butterfish *(Odax pullus)*, and, in the past, most recreational nets were soaked overnight *(*Dawson 1991b*).* Exact configurations and deployment of gear varies with target species.

To begin to quantify the level of bycatch in this region, Dawson (1991b) conducted fisherman interviews during 1984-1988 and found that at least 230 SI Hector's dolphins had died due to entanglement in commercial and recreational gillnets in the Pegasus Bay and Canterbury Bight region during this period. Of the entanglements documented by Dawson (1991b), most occurred within 4 nmi (7.4 km) of the shore (89%) and in water less than 20 m deep (86%). The deepest gillnet entanglement occurred in a commercial net in water 46 m deep. The large majority (91%) of entanglements occurred in spring and summer (November – February), when commercial and recreational fishing levels increased and when Hector's dolphins tend to move inshore. Ages of the entangled dolphins that were examined (n=43) ranged from younger than one year to about 20 years old, but a high proportion (63%) were three years old or younger, suggesting that younger dolphins are especially vulnerable to entanglement (Dawson 1991b). Although bycatch in trawls was not specifically examined in this study, Dawson (1991b) also

reported retrieving four SI Hector's dolphins that had died in trawl nets. Overall, this level of bycatch (i.e., 230 over four years or about 57.5 entanglement mortalities per year), greatly exceeded the estimated population growth rate for this regional population (1.8 – 4.9% or 13.3 - 36.3 individuals per year) (Dawson and Slooten 1988b, Slooten and Lad 1991). Subsequent analyses based on observer data, suggest that bycatch rates during this period (1984-1988) were actually much higher, averaging 100 dolphins per year (Davies *et al.* 2007).
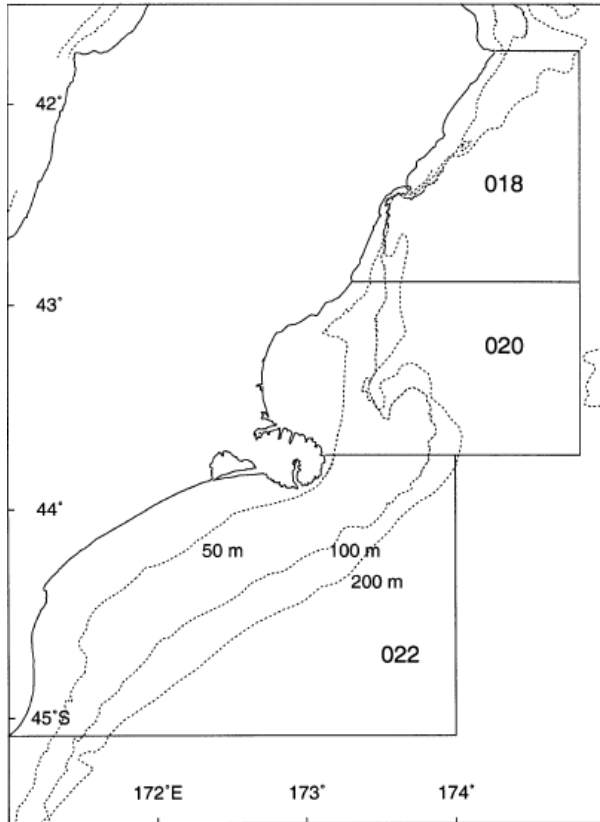

Figure 11. Fisheries statistical areas 018, 020, and 022 along the east coast of the South Island. The 50 m, 100 m, and 200 m depth contours are shown. (From Baird and Bradford 2000).

Following this first assessment by Dawson (1991b), bycatch in the Pegasus Bay and Canterbury region was again assessed using observer data collected for the 1997-1998 fishing season (Baird and Bradford 2000, Starr and Langley 2000). Observed during this fishing season were 214 set gillnets (of 945) targeting sharks and elephant fish, and 434 trawls (of 20,116) targeting mainly red cod (*Pseudophycis bachus*), flatfish, and tarakihi (*Nemadactylus macropterus*). Vessels were observed in statistical areas 018, 020, and 022, with primary focus on the latter two areas (Figure 11); and observed fishing extended out to the 200 m depth contour. During the study, a total of 8 SI Hector's dolphins were captured in set nets, and six of these dolphins were captured in setnets targeting sharks (Baird and

Bradford 2000, Starr and Langley 2000). Across statistical areas 020 and 022, estimated bycatch of SI Hector's dolphins in setnets for the season was 18 (CV = 38%, Baird and Bradford 2000). Observer coverage was too low in area 018 (6%) to produce a reliable estimate for this area. Because only one SI Hector's dolphin mortality was observed in a trawl net during the season and observer coverage was very low, a calculation of bycatch by the trawl fishery was not possible (Baird and Bradford 2000). Recreational gillnetting was not assessed by Baird and Bradford (2000), but during a subsequent summer (2000–2001) five Hector's dolphin mortalities occurred in gill nets that were likely set by recreational fishermen (Dawson *et al*. (2004), citing DOC and MPI, 2001).

Released in 2007, the Threat Management Plan for Hector's dolphins identified set gillnetting as the greatest source of human-caused mortality of Hector's dolphins (MFish and DOC 2007b). Between 1921 and when the plan was drafted, the DOC incident database indicated that 32% of all reported incidents and 63% of incidents with an established cause of death were attributable to set net entanglement (MFish and DOC 2007b). Over this same time period, there had also been 19 reports of Hector's dolphin mortalities due to trawls, which corresponds to 9% of reported incidents with a known cause of death. All 19 of these reports occurred off the South Island within 2 nmi of shore (MFish and DOC 2007b). Entanglement deaths of SI Hector's dolphins have also occurred in pot traps (e.g., rock lobster pots). Three incidents were reported (in 1989, 1997, and 2004) and all occurred off Kaikoura, which is along the northeast coast of the South Island (MFish and DOC 2007b).

As previously mentioned, the DOC established the BPMMS in 1988 in reaction to the growing concern over bycatch of Hector's dolphins. When it was first established, the sanctuary extended from Sumner Head to the Rakaia River and out to 4 nmi, covering an area of about 1,140 sq km. All gillnetting within the sanctuary (with some harbor exceptions) was prohibited from November through February, and additional gear restrictions that applied throughout the remainder of the year essentially resulted in a ban of commercial gillnetting within the sanctuary (Dawson and Slooten 1993). Additional restrictions on recreational gillnetting, such as limiting fishing to daylight hours only and requiring
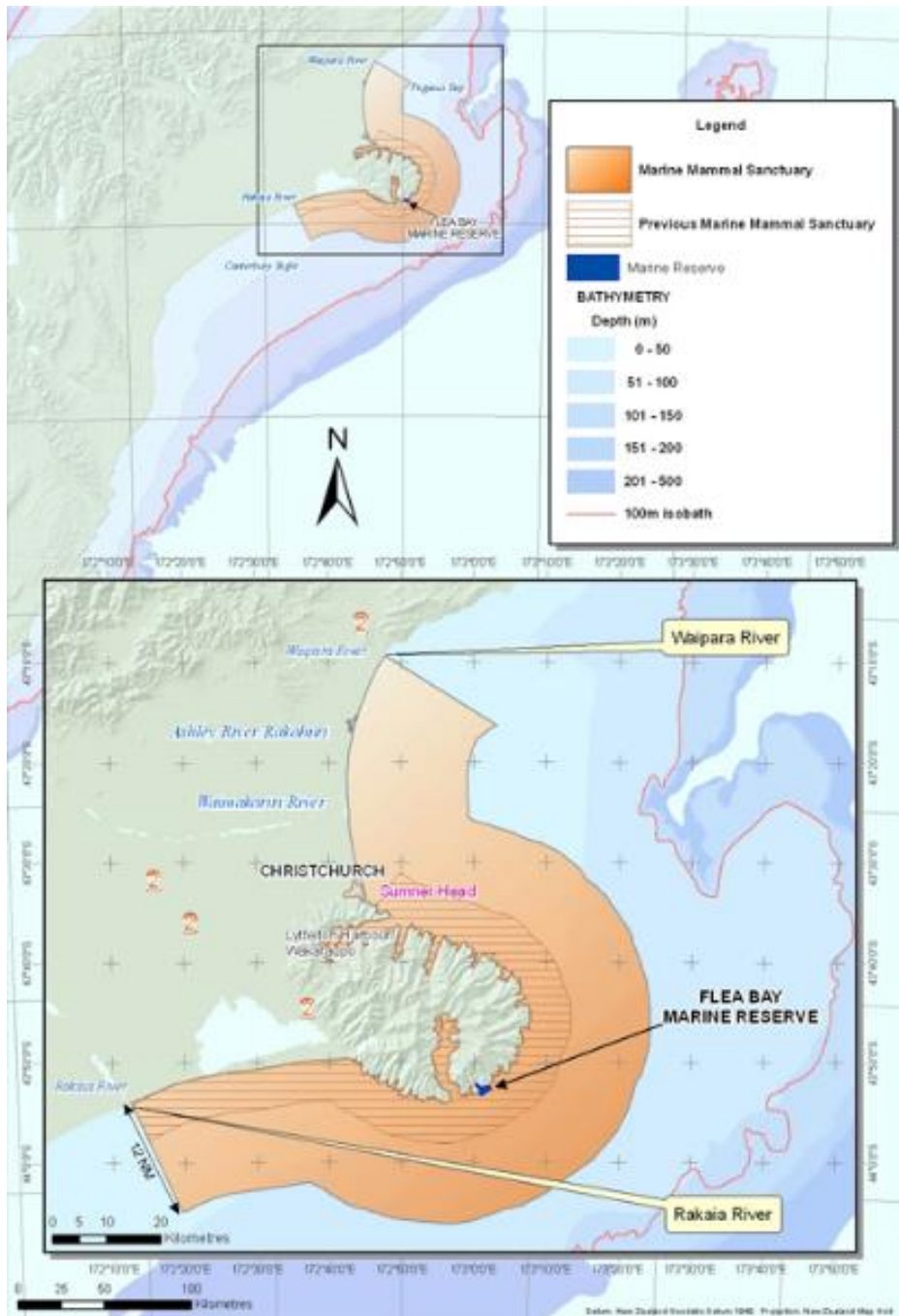
Figure 12. The Banks Peninsula Marine Mammal Sanctuary. Established in 1988, the sanctuary was later expanded in 2008 and currently encompasses about 4,130 sq. km and 389 km of coastline. Today's sanctuary extends from the mouth of the Rakaia River to the mouth of the Waipara River and out to 12 nmi from the coast. (Map from www.doc.govt.nz.)

continuous tending of nets, were also enacted to help further reduce bycatch mortality. Based on fisheries observer data, bycatch in gillnets was occurring to the immediate north and south of the sanctuary at unsustainable levels (Baird and Bradford 2000, Dawson and Slooten 2005) and there was little evidence of improved survival of SI Hector's dolphins within the sanctuary (Cameron *et al*. 1999; however, see Burkhart and Slooten 2003). In recognition that further protection of SI Hector's dolphins was still needed, in May 2008, the DOC announced that the sanctuary boundaries would be expanded to the north and south and out to 12 nmi offshore (Figure 12; DOC 2008). The sanctuary currently encompasses about 4,130 sq. km and 389 km of coastline. A prohibition on commercial trawling within 2 nmi of the coast was also enacted, but no restrictions on fishing activities were applied to the area beyond the original 4 nmi sanctuary boundary (MFish and DOC 2007b). Only acoustic seismic surveys are currently regulated within the sanctuary area between 4 and 12 nmi (DOC 2008).

In May 2008, the MPI also enacted a suite of fisheries restrictions to reduce bycatch of SI Hector's dolphin throughout the South Island. Along the east and south coasts, from Cape Jackson in the Marlborough Sounds to Sandhill Point east of Fiordland, commercial gillnetting was banned out to 4 nmi from shore, except at Kaikoura, where it was banned out to 1 nmi, and in Te Waewae Bay, where it is banned out to about 9 nmi from shore (Figure 13; MFish 2008). Recreational gillnetting was allowed to continue in specified harbors and estuaries; and, in the case of flatfishing, gillnetting was permitted from April through September in the upper reaches of four harbors on Banks Peninsula, and in a similar area in Queen Charlotte Sound. Trawling was also prohibited between these same points along the east and south coasts out to 2 nmi, with an exception for trawls using a low headline net (used to target flatfish, MFish 2008). On the west coast of the South Island, again with some exceptions for certain harbors, inlets, estuaries, river mouths and lagoons, recreational set netting was banned year-round in waters out to 2 nmi and from Cape Farewell on Farewell Spit to Awarua Point north of Fiordland, and commercial set netting was banned in the same area from December through February (Figure 13; MFish 2008). No trawling prohibitions were implemented for the west coast, and no dolphin protection measures were instituted along the north coast.
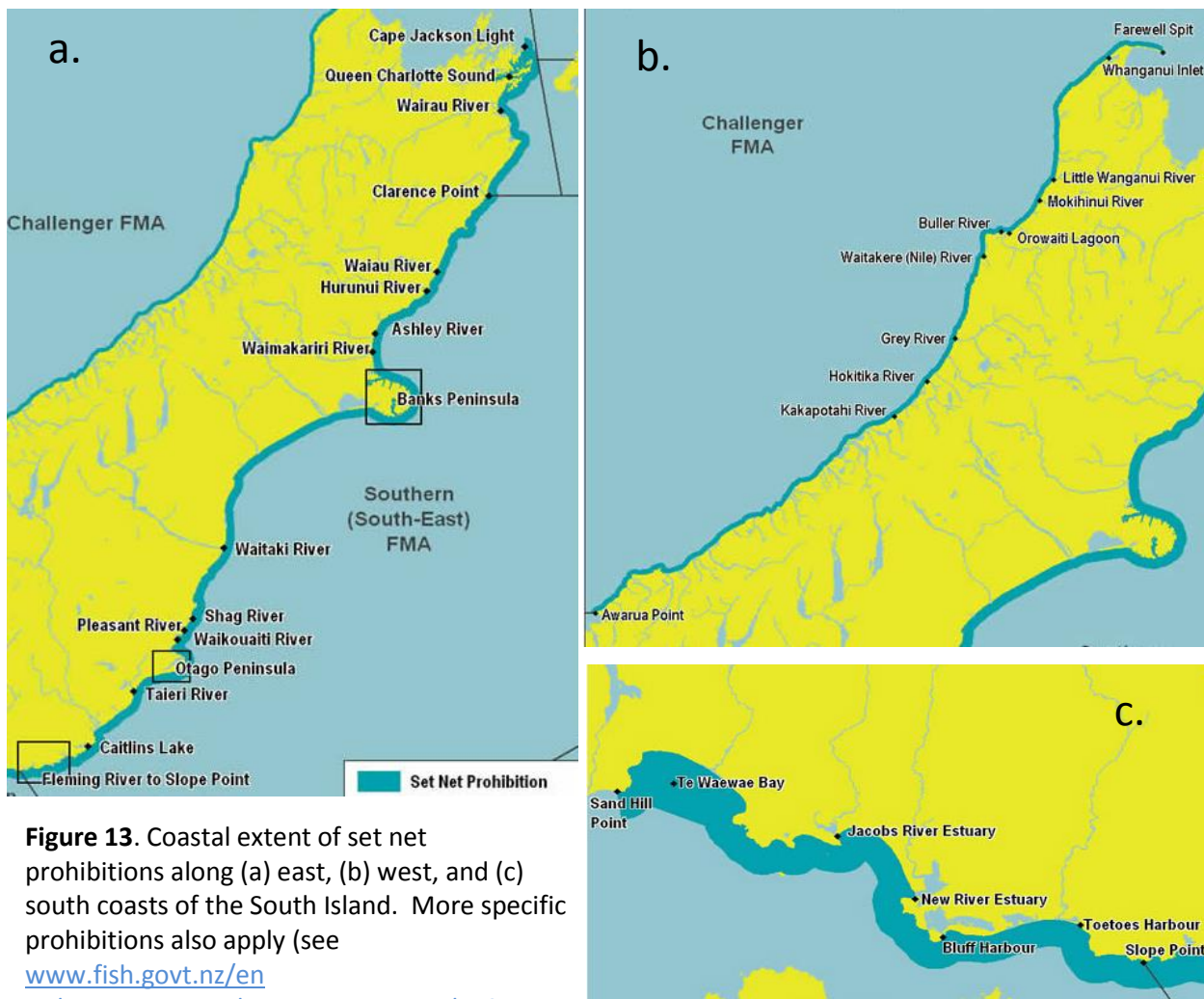
Figure 13. Coastal extent of set net prohibitions along (a) east, (b) west, and (c) south coasts of the South Island. More specific prohibitions also apply (see www.fish.govt.nz/en nz/Environmental/Hectors+Dolphins/default.htm?wbc_purpose=Basi%252f).

Some amendments and changes to the 2008 fishery restrictions have been made. For example, in 2011, following judicial review and reconsideration by the MPI, the targeted butterfish commercial fishery was exempted from the set net closure on the east coast. This fishery and associated exemption occur in the northern portion of the South Island (Figure 14, MPI 2011a, 2011b). This decision was based on a conclusion that the butterfish fishery poses a relatively low entanglement risk because it employs short nets (60 m) within 200 meters of shore with very short set durations (MPI 2011a). There had also been no records of dolphin mortalities in commercial butterfish nets (MPI 2011a). In 2012, MPI also opened this area to recreational set net fishing between January 1 and April 30, provided that fishers remain with their nets while fishing and that nets be set no farther than 200 m from shore (MPI 2012). These activities were

exempted from the set net closure, because they were thought to pose very limited risk to Hector's dolphins (MPI 2011a, MPI 2012).
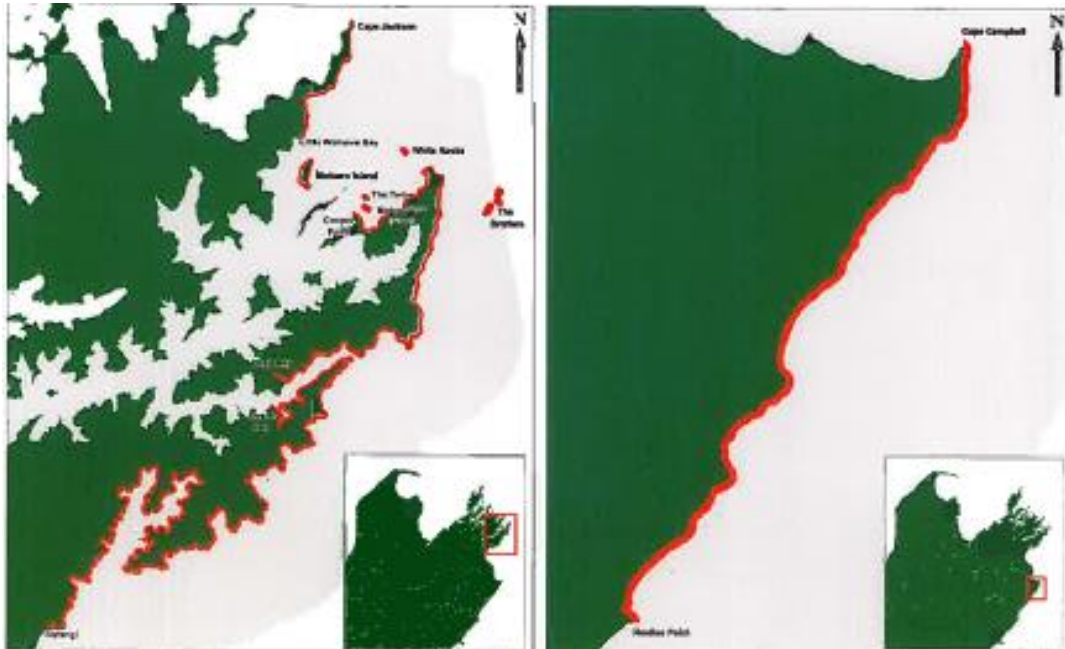

Figure 14. Areas on the north eastern coast of the South Island where commercial and recreational net setting is allowed out to 200 m (red areas). (Map from MPI 2012).

Other voluntary practices were also adopted and have been in use around the South Island since 2002. These measures include deployment of pingers and other modification to fishing activities. The extent to which voluntary measures are being implemented is unclear, and there is no evidence that pingers are effective in reducing bycatch of Hector's dolphins (Stone *et al*. 2000b, Dawson 1998). Therefore, we did not evaluate these voluntary measures further.

Despite the gradual increase in fishing restrictions around the South Island, exposure of SI Hector's dolphins to fishing activity remains fairly high throughout the South Island. On the west coast, where the dolphins are known to occur year-round and range to about 9.5 nmi offshore (Mackenzie and Clement 2016), commercial gillnetting is only prohibited out to 2 nmi for just three months of the year, and there are no prohibitions on trawling. Survey sightings off the south coast indicate that the dolphins at least occasionally occur as far as 9.6 nmi from shore and outside of protected areas (Clement *et al.* 2011). On the east coast, a substantial portion of the population is distributed well beyond the current closed areas throughout the year and particularly in winter months (see Figure 15; Rayment *et al*. 2006, Mackenzie and

Clement 2014). Furthermore, gillnetting is still allowed within the BPMMS in waters between the original (4 nmi) and the extended boundary (12 nmi; see Figure 16). The International Union for Conservation of Nature (IUCN, 2012) recommended banning gillnet and trawl fishing out to 100m water depth throughout the range of the SI Hector's dolphins.

Since 2008, bycatch of Hector's dolphins has continued along all coasts. The DOC Incident database (www.doc.govt.nz/our-work/hectors-and-maui-dolphin-incident-database/) lists 13 entanglement mortalities between May 2009 and April 2015; and, in 2012, two Hector's dolphins were found stranded and wrapped in a gillnet just north of Christchurch (Slooten 2013). As a caveat, the large majority of mortalities reported in the database are listed as having unknown or indeterminable causes, and Pichler *et al.* (2003) reported that of the dolphins caught by commercial and recreational gillnet fishers and brought in for necropsies, only about half have discernable net markings.
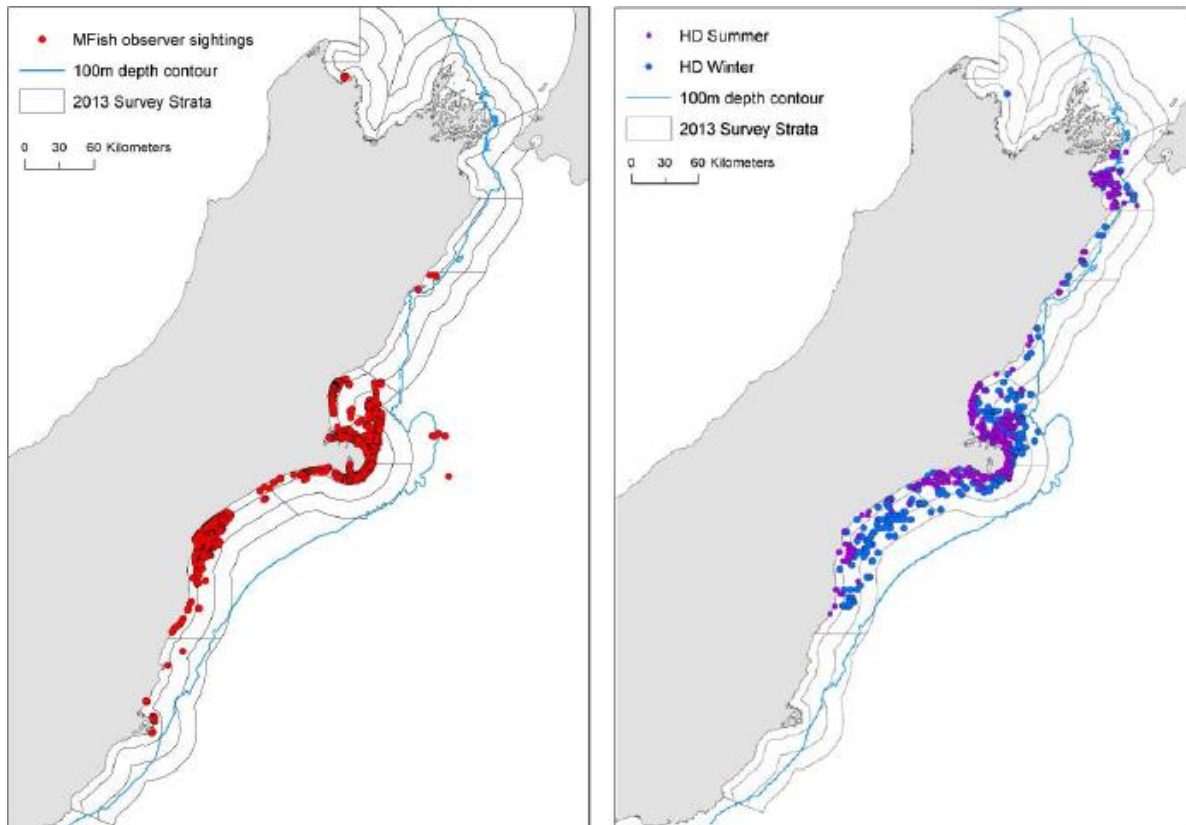
Figure 15. Sightings data from the MFish observer program collected in 2009-2010 (left panel) and from the aerial surveys conducted by Mackenzie and Clement in 2012-2013 (right panel). Gray contour lines represent aerial survey strata boundaries of 4 nmi, 12 nmi, and 20 nmi. The distribution data shown clearly indicate that a substantial portion of the population moves outside of the 4 nmi gillnetting closed area and beyond the 2 nmi trawling closed area. (Adapted from Mackenzie and Clement 2014).

Figure 16. Survey sightings from Mackenzie and Clement (2014) in relation to the previous and current BPMMS boundaries. Summer (red dots) and winter (blue) sightings are shown. Corresponding percentages representing the proportion of the summer (red lines) and winter (blue lines) population sighted within the old 4 nmi and current 12 nmi BPMMS boundaries. (From Mackenzie and Clement 2014).

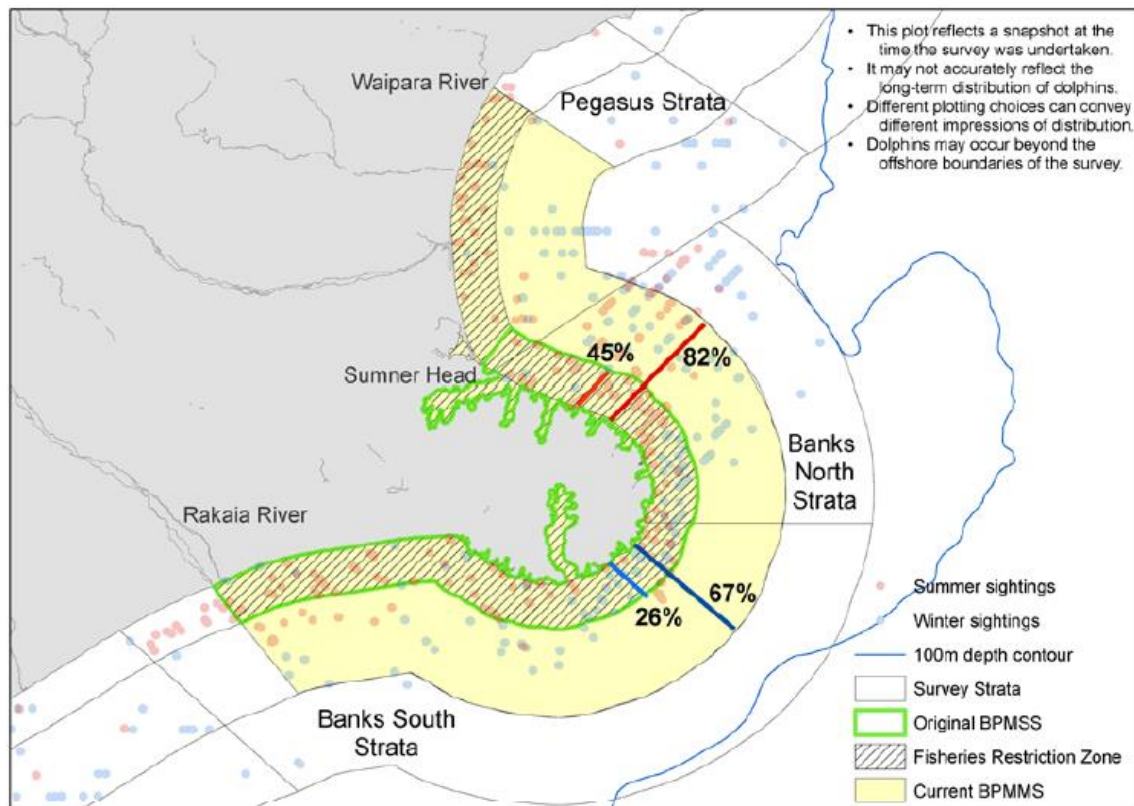Almost three decades of protection at BPMMS has improved survival of SI Hector's dolphins, but the local population of SI Hector's dolphins may still be declining. In the most recent assessment of this population, Gormley *et al.* (2012) conducted a mark-recapture analysis of photographically identified dolphins (n=462) from 1986 to 2006 to compare annual survival rates before and after establishment of the sanctuary and associated gillnetting restrictions. Results indicated that between the two time periods, mean survival probability increased by 5.4% (from 0.863 to 0.917), which corresponds to a 6% increase in population growth. This finding strongly suggests that the sanctuary has led to an increase in survival and is providing a conservation benefit to the local, resident population around Banks Peninsula. However, the population projections with the post-sanctuary survival rate also corresponded to a mean annual population decrease of 0.5% per year, with only 41% of the model simulations resulting

in a population increase (Gormley *et al*. 2012). As noted by Gormley *et al.* (2012), this finding is consistent with other research indicating that the BPMMS is too small to allow recovery of this Hector's dolphin population (Slooten and Dawson 2008, Rayment *et al*. 2010b, Slooten and Dawson 2010).

Results of a PBR analysis presented in the Threat Management Plan indicate that all populations of Hectors' dolphins are threatened by even low levels of human-caused mortality (MFish and DOC 2007b). For example, when applying a recovery factor such that the population is expected to increase at a rate only slightly less than an un-perturbed population, the PBR analysis suggests that the ECSI population can sustain about 2-4 human-caused mortalities per year. Using a default recovery factor value (0.5), the PBR analysis suggests the abundance of the ECSI population could be maintained with up to about 13 human-caused mortalities per year (MFish and DOC 2007b). While the DOC is not necessarily suggesting that 13 mortalities per year is an acceptable level of bycatch mortality, the PBR analysis does provide an indicator of the vulnerability of the population to human-sources of mortality and is useful in making management decisions. To put these PBR results in context, in 2009, based on very low observer coverage of commercial gillnet vessels from May 2009 through April 2010 (about 15.8% of fishing days and about 13% of total sets), three SI Hectors' dolphin mortalities were recorded from the ECSI (MPI 2011b, Slooten and Davies 2012). Slooten and Davies (2012) analyzed this data and estimated that a total of 23 SI Hector's dolphins (range of 4-48, CV = 0.21) were caught off the ECSI that year. This estimated level of bycatch in the commercial gillnet fishery of ECSI is 18- 40 times greater than the estimated PBR (Slooten and Davies 2012). Overall, these findings do not provide compelling evidence that bycatch mortality for all fisheries is below a level that will allow recovery of the ECSI population of SI Hectors' dolphins.

Evidence from other modelling efforts suggests that the subspecies will continue to decline due to bycatch under current management measures. The risk analysis by Davies *et al*. (2008) using a Bayesian population model indicated that all populations are more likely to decline than increase under existing management, and that the small SCSI population was vulnerable to declining to a level at which the population could become subject to depensation (i.e., reduced per-capita growth rate at low densities). The population viability analysis by Slooten and Dawson (2010), which relied on commercial gillnet observer data to estimate bycatch (from Baird and Bradford 2000), projected that the west coast population would continue to decline (by just over 1,000 individuals by 2050), the Banks Peninsula population would continue to decline, and the remainder of the east coast population would slowly increase (by 450 individuals by 2050). The state-specific modelling work of Secchi *et al.* (2004a) also indicated that the Banks Peninsula population was declining and had a low recovery potential. In their review of risk assessments for Hector's dolphins, Slooten and Davies (2012) found that despite

the differing modelling approaches and assumptions, the risk assessments were highly consistent and were in general agreement that recovery of SI Hectors' dolphins is unlikely under the current level of protections. Adding a level of uncertainty to these modelling results is the fact that these models rely on abundance estimates that were available at the time, and more recent surveys (e.g., Mackenzie and Clement 2014, 2016), which extended farther from shore, have since produced a much larger abundance estimate for Hector's dolphins on the east coast of the South Island. However, an analysis by Slooten (2015b) suggests that the rate of population increase or decline is relatively insensitive to population size and is highly sensitive to estimates of fishing effort and bycatch.

In summary, we conclude the existing measures to address the threat of bycatch of SI Hector's dolphins are inadequate and that bycatch continues to pose a significant risk to the subspecies as a whole. The risk of bycatch in commercial and recreational, trawl and gillnet fisheries remains high given the known distribution of the dolphins relative to areas closed to fishing, especially on the west and north coasts (Faustino *et al*. 2013, Slooten 2013). While bycatch of SI Hector's dolphins has been slowed by the fisheries restrictions implemented in 2008, the available risk analyses indicate that population decline is expected to continue (Slooten and Dawson 2010, Gormley *et al*. 2012, Slooten and Davies 2012). We acknowledge there is uncertainty regarding these model results because they rely on earlier, lower abundance estimates for SI Hector's dolphins and relatively limited bycatch data. There remains a high degree of uncertainty regarding the actual bycatch rates occurring across all fisheries and all regions of the South Island. Finally, enforcement of the existing regulations may be insufficient. Illegal fishing has been reported for Banks Peninsula (Slooten and Davies 2012) and illegal fishing practices were discussed in the Threat Management Plan (MFish and DOC 2007b). There are insufficient data available to evaluate the level of compliance with existing regulations.

3.3.4.2 Mining and Acoustic Impacts
For both petroleum and minerals mining activities, a permit is generally required from local authorities under the Resource Management Act 1991 for mining activities within New Zealand's territorial sea (within 12 nmi from the coast). For mining activities beyond the territorial sea, the Environmental Protection Authority (EPA) manages the environmental effects of activity under the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (EEZ Act) and its regulations, which establish which activities require permits and impact assessments. Seismic surveys are permitted under the EEZ Act if they adhere to the Code of Conduct for Minimizing Acoustic Disturbance to Marine Mammals from Seismic Survey Operations (DOC 2013). Voluntary guidelines for minimizing acoustic disturbance of marine mammals during seismic surveys were first established in 2006, but with input from stakeholders and other interested parties, the DOC Minister and the Minister of Energy and

Resources revised these guidelines to reflect international best practices and released the voluntary "Code of Conduct for Minimizing Acoustic Disturbance to Marine Mammals from Seismic Surveys Operations" in 2012. In 2013, the DOC and MPI updated the guidelines again and announced a decision to make the code of conduct a mandatory standard. The mandatory code of conduct applies to Territorial waters, the Exclusive Economic Zone (EEZ) of New Zealand, and within all marine mammal sanctuaries, and includes requirements for planning, operations, monitoring, and reporting. The 2013 code of conduct is currently undergoing review and may be further augmented to increase protections for Hector's dolphins and other species of concern. Discharge management plans associated with mining activities, also must be approved under the Maritime Rules Part 200, Maritime New Zealand prior to drilling.

As part of the Threat Management Plan for Hector's dolphins, the DOC expanded BPMMS in 2008 and established an additional three marine mammal sanctuaries to help manage non-fishing-related threats to Hector's dolphins – the Catlins Coast, Clifford and Cloudy Bay, and Te Waewae Bay Marine Mammal Sanctuaries (MMS). The Catlins Coast MMS lies along the SCSI between Three Brother's Point and Busy Point and extends 5 nmi to 6.9 nmi offshore. The sanctuary encompasses about 660 sq km of marine habitat and 161 km of coastline. The Clifford and Cloudy Bay MMS, which lies on the northeast coast, includes about 1,427 sq km and 338 km of coastline between Cape Campbell to Tory Channel, and extends 12 nmi offshore. The Te Waewae Bay MMS includes this entire SCSI bay and encompasses about 359 sq km of marine habitat and 113 km of coastline. Protections for SI Hector's dolphins that accompanied the expansion of BPMMS and the designation of these three additional sanctuaries were specific requirements for conducting seismic surveys. Included among the requirements for seismic surveys are mandatory notification prior to conducting surveys, mandatory reporting of any interactions with dolphins, and presence of qualified marine mammal observers on all survey ships (*Gazette*, 23 September 2008). There are no additional restrictions on mining activities within the sanctuaries.

Overall, while there is a clear regulatory process in place for reviewing and permitting mining activities, given the existing information, it is not clear whether existing management measures are adequate to minimize acoustic and other impacts to SI Hector's dolphins such that these activities do not pose a threat to the subspecies.

3.3.4.3 Additional Protections under the Marine Mammals Protection Act of 1978
The SI Hector's dolphin is classified as "threatened" under the MMPA (1979); however, as with Maui's dolphins, no PMP has been developed. Thus, no maximum allowable level of mortality has been established.

Pursuant to Marine Mammal Protection Regulations of 1992, all boaters, both recreational and commercial must adhere to certain rules when operating around marine mammals. For example, no more than 3 vessels and/or aircraft are allowed within 300 m of any marine mammal; speeds must be kept to 'no wake' speeds when within 300 m of any marine mammal; swimmers are prohibited from swimming with dolphin pods with very young calves; and boats are prohibited from circling, obstructing, or cutting through any group (MMPR 1992, part 3). Whether these regulations, and the associated education and enforcement of these regulations, are adequate is difficult to determine. As discussed previously, there is evidence of behavioral changes associated with tourism activity, and there are a few documented boat strikes of SI Hector's dolphins. We explore the adequacy of regulation of the tourism industry further in the section below.

3.3.4.4. Tourism

The dolphin-watching industry in New Zealand is regulated under the Marine Mammals Protection Regulations (MMPR), which were revised in 1992 in response to the growth in marine mammal-based tourism (Constantine (1999), citing Donoghue 1996). Among other provisions, these regulations govern the issuance of permits to commercial operators and, as discussed above, the behavior of vessels around dolphins. As a permit issuance criterion, commercial tour operators are required to ensure that their activities have "no significant adverse effect" on their targeted population (MMPR, 1992; Appendix 1.4). Given the high level of commercial dolphin watching operations in some portions of the SI Hector's dolphin's range, the repeat exposure of individual dolphins to vessels and/or 'swim-with' activities, and the potential linkage to long-term biological consequences, it is possible that the current level of tourism is having a significant adverse impact on the subspecies. We find that there are insufficient data by which to verify that this permit issuance criterion is being met.

Compliance monitoring is limited and sufficient quantitative data are not available to assess compliance with the regulations by commercial and recreational boaters (MFish and DOC 2007b). In terms of complying with the prohibition on approaching dolphins in an aggressive manner, Martinez (2010) observed that, although compliance with this regulation by commericial vessels was fairly high in Akaroa Harbor (78.6%), it was not universal. Martinez (2010) found that recreational jet-skiers were two to six times more likely to approach Hector's dolphins in an aggressive manner, which had a tendency to alter the dolphins' behavioral state. Martinez (2010) makes several recommendations for reducing the impact of commercial tours, such as prohibiting the use of sounds to purposely attract the dolphins and halting the common practice of "handing over" dolphin groups from one tour boat to another by managing departure times for tours.

To help raise awareness and educate boaters about the regulations governing the operation of vessels around marine mammals, the DOC has initated the SMART program (an acronym for 'Sustainable Marine Mammal Actions in Recreation and Tourism') and training course. Commercial operators that participate can then be labelled as SMART operators and promoted by DOC to tourists. This is a proactive program designed to educate boaters and also promote commercial operators that intend to adhere to the regulations. Whether this program has resulted in improved compliance by recreational boaters and swimmers is unknown. In addition, following almost two decades of consideration and judicial review, the DOC established the Akaroa Harbor Marine Reserve at the mouth of Akaroa Harbor. While the reserve designation does not prohibit any eco-tourism activities, the removal and disturbance of marine life within the reserve is technically prohibited (http://www.doc.govt.nz/nature/habitats/marine/marine-protected-areas/).

Overall, while the DOC has gradually increased its management and outreach efforts regarding sustainable tourism, in the absence of additional data from other locations and for both recreational and commercial boaters and swimmers, a firm conclusion that the existing regulation of commercial tourism operations is adequate to ensure the conservation of SI Hector's dolphins is not possible. The available information indicates that dolphin-watching and 'swim-with' activities are not benign activities even when conducted according to the MMPR, and that while compliance with existing regulations may be high among commercial operators, the same is not necessarily true of recreational boaters.

3.3.5 Other Natural or Human Factors

Other potential threats to SI Hector's dolphins include vessel noise, trophic effects of fishing, and climate change; however, there are no data available to assess how or whether these factors are contributing to the overall level of human-caused mortality or population trends. Boat strikes, however, are a documented source of mortality for Hector's dolphins, and the Threat Management Plan identifies vessel traffic as a threat that can result in disturbance and mortality (MFish and DOC 2007b). Vessel traffic has increased around the South Island, especially in areas more densely populated by people, and reports of cetaceans with propeller scars has increased (Martinez 2010). Stone and Yoshinaga (2000) reported the death of two calves on consecutive days in Akaroa Harbor. In 1999, two calves, both estimated to be younger than 4 weeks old, were recovered on successive days from Akaroa Harbor, and autopsy results confirmed that cause of death for one calf was collision with a boat and for the other calf, a propeller strike (Stone and Yoshinaga 2000). Stone and Yoshinaga (2000) suggest that mother and calf pairs may be less capable of evading boats if they are approached. Although the cause of mortality was unknown, the Threat Management Plan also states that there were an additional nine cases from around the South Island in which cause of death was some form

of trauma (MFish and DOC 2007b). Overall, data are too limited to assess the rate of boat strikes, but existing information clearly indicates that boat strikes are contributing to the total level of human-caused mortality.

4.0 EXTINCTION RISK

4.1 Approach to Assessing Extinction Risk

The demographic risk analysis described in this section of the report is essentially an assessment of the manifestation of threats that have contributed to each subspecies' current status. Data and information about demographic risks to each subspecies was considered according to four categories - abundance, population growth/ productivity, spatial structure/ connectivity, and genetic diversity. Each of these demographic threat categories was then rated according to the following qualitative scale:

> **1 - Very low risk**: It is unlikely that this factor contributes significantly to risk of extinction, either by itself or in combination with other demographic factors.
>
> **2 - Low risk:** It is unlikely that this factor contributes significantly to long-term or near future risk of extinction by itself, but there is some concern that it may, in combination with other demographic factors.
>
> **3 - Moderate risk:** This factor is likely to contribute significantly to long-term risk of extinction, but does not by itself constitute a danger of extinction in the near future.
>
> **4 - High risk:** This factor contributes significantly to long-term risk of extinction and is likely to contribute to short-term risk of extinction in the near future.
>
> **5 - Very high risk**: This factor by itself indicates danger of extinction in the near future.

(Note: The term "significantly" is used here as it is generally defined – i.e., in a sufficiently great or important way as to be worthy of attention.)

We elected to conduct this analysis on the subspecies level, because the subspecies have their own discrete distributions, experience different threat exposures, and are subject to differing management efforts. There are sufficient data to evaluate extinction risk at the subspecies level, and much of the relevant studies are specific to a particular subspecies or even a particular population (in the case of the SI subspecies). This approach also presents sufficient information should a composite risk assessment be desirable at a later stage.

As a concluding step in this status review, after considering all of the available information regarding demographic and other threats to the subspecies, we rated each subspecies' extinction risk according to the following qualitative scale:

High risk: A species with a high risk of extinction is at or near a level of abundance, productivity, spatial structure, and/or diversity that places its continued persistence in question. The demographics of a species at such a high level of risk may be highly uncertain and strongly influenced by stochastic or depensatory processes. Similarly, a species may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; or disease epidemic) that are likely to create such imminent demographic risks.

Moderate risk: A species is at moderate risk of extinction if it is on a trajectory that puts it at a high level of extinction risk in the foreseeable future (see description of "High risk" above). A species may be at moderate risk of extinction due to projected threats or declining trends in abundance, productivity, spatial structure, or diversity. The appropriate time horizon for evaluating whether a species is more likely than not to be at high risk in the foreseeable future depends on various case- and species-specific factors. For example, the time horizon may reflect certain life history characteristics (e.g., long generation time or late age-at-maturity) and may also reflect the time frame or rate over which identified threats are likely to impact the biological status of the species (e.g., the rate of disease spread).

Low risk: A species is at low risk of extinction if it is not at moderate or high level of extinction risk (see "Moderate risk" and "High risk" above). A species may be at low risk of extinction if it is not facing threats that result in declining trends in abundance, productivity, spatial structure, or diversity. A species at low risk of extinction is likely to show stable or increasing trends in abundance and productivity with connected, diverse populations.

4.2 Demographic Risks for Maui's Dolphin

4.2.1 Abundance and Trends

As discussed in detail above in section 2.8.1, the latest visual survey abundance estimate for Maui's dolphins, using data collected in 2004, is 111 dolphins (95% CI = 48-252, Slooten *et al.* 2006a). A more recent abundance estimate, based on a genetic mark-recapture analysis of samples collected in 2010 and 2011, is 55 dolphins over one-year of age (95% CI: 48 – 69, (Hamner *et al*. 2012b). Small populations are considered to face higher risks of extinction from a range of factors, including stochastic demographic processes, genetic effects, and

environmental catastrophes; and various theoretical abundance thresholds have been proposed as indicators of relative extinction risk (Gilpin and Soulé 1986, Allendorf *et al*. 1987, Mace *et al*. 2008). Both of the most recent abundance estimates for Maui's dolphins are well below commonly cited theoretical thresholds indicating a very high risk of extinction - e.g., 250 total individuals (Allendorf *et al.* 1987) and 250 mature individuals (Mace *et al.* 2008).

Although historical abundance estimates are not available, Slooten (2007a) estimated population abundances for 1970 by back-calculating using a population estimate of 117 dolphins (CV= 0.44) and estimates of fishing effort and rate of dolphin bycatch. Results of this work, which was based on the limited data available, suggested that the abundance of Maui's dolphins in 1970 was about 1,729 dolphins (CV= 0.51, Slooten 2007, Slooten and Dawson 2010). Martien *et al*. (1999) also projected numbers back to 1970 using an earlier abundance estimate published by Dawson and Slooten (1988; i.e., 134 dolphins), and estimated there were about 448 Maui's dolphins in 1970. Although there are differences in the models, assumptions, input data, and results of these two analyses, both of these estimated abundances for 1970 suggest the Maui's dolphin population has declined by about 90% when compared to the current abundance estimate of 55 dolphins over 1-year of age.

As discussed earlier, there is evidence that suggests the abundance of Maui's dolphins may continue to decline. For example, an annual rate of decline of 3.0% per year (95% CL: - 11% to + 6%) and an annual survival rate of 84% (95% CI = 0.75 – 0.90) was estimated by Hamner *et al.* (2012b). Although this result was somewhat equivocal given the large confidence interval, a projected decline is supported by the trend analysis conducted by Wade *et al.* (2012) using six, different abundance estimates generated from 1985 to 2011 (captured in Table 1). Wade *et al.* (2012) calculated a statistically significant declining trend of -3.2% per year from 1985 to 2011 (90% CI = -5.7% to -0.6%, p = 0.029). As noted by Wade *et al.* (2012), the abundance trend could be interpreted as having a 97.1% probability of being less than zero.

Overall, the current population estimates of fewer than 100 dolphins and evidence of possible continued decline constitute a **very high risk** to the continued existence of this subspecies.

4.2.2 Population Growth
Fecundity (i.e., the number of female offspring per female per breeding season) of Maui's dolphins is relatively low (0.165 to 0.25, Secchi *et al*. 2004b), with females having calves every two to four years after reaching maturity at about 7 years of age (Slooten and Dawson 1994, Dawson 2009). Given an estimated lifespan of about 22 years, later maturity, and low fecundity, Maui's dolphins are thought to have a low population growth rate (Dawson 2009).

The estimated survival rate suggests an annual mortality rate of 17% per year for ≥ 1 year old dolphins (Hamner *et al*. 2012b). The estimated survival rate of 0.83 is fairly precise and

consistent with previous estimates for SI Hector's dolphins ≥ 1 year old (e.g., 0.77 – 0.89, Slooten and Lad 1991, Slooten *et al*. 1992, Slooten and Dawson 1994, Cameron *et al*. 1999).

Based on modelling work, population growth for Maui's dolphins has been projected to be negative given existing human sources of mortality (Slooten and Lad 1991, Currey *et al*. 2012). Modelling results also indicate that, in the absence of all human impacts, population growth may be about 2% per year (Slooten and Lad 1991, Currey *et al*. 2013).

Overall, we consider this demographic factor to constitute a **high risk** for Maui's dolphins.

4.2.3 Spatial Structure and Connectivity

Maui's dolphins, which are considered to have once ranged along the entire coast of the North Island (Russell 1999, Dawson *et al*. 2001b, Baker *et al*. 2002, Du Fresne 2010), are now generally restricted to about 300 km along the west coast of the North Island (Figure 2b; Oremus *et al*. 2012). Ferreira and Roberts (2003) cite a personal communication stating that, prior to the 1960s, there were regular sightings of Maui's dolphins as far south as Paraparaumu. The majority of sightings are currently concentrated within approximately 139 km of their remaining range (Oremus *et al*. 2012).

While there is no indication of spatial structuring within the subspecies, data do indicate that home ranges of individuals are probably small. Using genetic recapture data collected over two summers (2010 and 2011) for 6 dolphins along the west coast of the North Island, Oremus *et al.* (2012) calculated a minimum along-shore home range of 35.5 km (SE= 4.03). Additional data collected on SI Hectors' dolphins around Banks Peninsula indicate that home ranges generally do not exceed 60 km and movements over 100 km are probably rare (Hamner *et al.* 2012b). At the level of the species, the range of Hector's dolphins is fragmented - possibly due to strong philopatry and ecological preferences (Dawson and Slooten 1993, Pichler and Baker 2000). Based on analyses of mtDNA, the North Island subspecies has been isolated from the South Island populations for up to 16,000 years (Pichler *et al*. 2001). Collectively, this information suggests gene flow will be limited among populations of Hectors' dolphins that are over 100 km apart, and indicates that gene flow has not occurred between the two subspecies for a very long time.

Longer-range movements of SI Hector's dolphins do, however, appear to occur, at least on occasion. Recent genetic data indicate that two female SI Hector's dolphins were living within the range of Maui's dolphins, and four dead SI Hector's dolphins were found along the coast of the North Island (Hamner *et al.* 2012b; Hamner *et al*. 2014a). These data provide evidence of long-distance (> 400 km) dispersal of SI Hector's dolphins. However, there is no evidence of recent mating between the two subspecies of Hector's dolphins (Hamner *et al*. 2012b, Hamner

et al. 2014a). While a very limited potential for migration does exist (Pichler 2002), the genetic consequences of interbreeding are uncertain and hypothetically could be beneficial or detrimental for Maui's dolphins (Hamner *et al.*, 2014a).

Overall, we conclude this demographic factor constitutes a **moderate risk** for Maui's dolphins.

4.2.4 Genetic Diversity

Genetic diversity in Maui's dolphins is currently very low. Pichler (2002) analyzed microsatellite DNA for Maui's dolphins across six loci (n = 4 to 12) and reported an average of 1.5 alleles per locus, three of which were fixed (i.e., 1 allele), and an overall low heterozygosity (0.083 – 0.25). Analyses of contemporary mtDNA samples also indicate a single maternal lineage (Pichler 2002, Hamner *et al*. 2012a). This level of haplotype diversity (i.e., *h* = 0) is well below the expected range of 0.70 – 0.92 for other abundant odontocete species (Pichler and Baker 2000), and is only seen in several other rare marine mammals (e.g., vaquita (*Phocoena sinus),* north Atlantic right whale *(Eubalaena glacialis)*, Dawson *et al*. 2001b).

Maui's dolphins are reproductively isolated from SI Hector's dolphins, and there has been no recent gene flow between the subspecies (Pichler *et al*. 2001, Hamner *et al*. 2012a). Hamner *et al*. (2012a) noted that some degree of inbreeding is inevitable for such a small, isolated population and also suggested that the significant deviation from a 1:1 sex ratio for stranded Maui's dolphins, due to an excess of females in their sample (41 females of 68 total Maui's dolphins), may be an indication of deleterious inbreeding effects.

Overall, Maui's dolphins have very low genetic diversity, are genetically isolated, and are vulnerable to inbreeding depression and the accumulation of deleterious mutations, which are serious concerns that can hasten the extinction of small populations (Lunch *et al*. 1995, Frankham 2005, O'Grady *et al*. 2006). Thus, we conclude this demographic factor constitutes a **high risk** for Maui's dolphins.

4.3 Demographic Risks for SI Hector's Dolphin

4.3.1 Abundance and Trends

The current abundance estimate for SI Hector's dolphins is 14,849 dolphins (95% CI = 11,923 – 18,492, Mackenzie and Clement 2016) and is based on a series of aerial surveys conducted between 2010 and 2015 along the north, east, west, and south coasts (Clement *et al*. 2011, Mackenzie and Clement 2014, Mackenzie and Clement 2006). This abundance estimate is greater than commonly cited theoretical abundances used as threshold indicators of a high risk of extinction – e.g., 2,500 total individuals (Allendorf *et al.* 1987) and 1,000 mature individuals

(Mace *et al.* 2008) - suggesting SI Hector's dolphins are not at high risk of extinction due to abundance alone.

Populations of SI Hector's dolphins have experienced substantial declines and available information suggests that the subspecies is likely to continue declining (Slooten and Lad 1991, Slooten *et al*. 1992, Burkhart and Slooten 2003). SI Hector's dolphin populations are estimated to have experienced declines of 20-73% since the 1970s following the expansion of commercial gillnetting in New Zealand (Slooten 2007a, Davies *et al*. 2008, Slooten and Dawson 2010). Evidence of a historical decline is also supported by the findings of Pichler and Baker (2000), who detected a significant decline in mtDNA diversity (from h = 0.65 to h = 0.35, p< 0.05) for ECSI Hector's dolphins in a comparison of contemporary (n=108) samples to historical samples (n=55) dating back to 1870. While there is strong evidence that adult survival in the ECSI population has improved following the implementation of fishing restrictions at BPMMS (0.863 (95% CI = 0.647 – 0.971) pre-sanctuary versus 0.917 (95% CI = 0.802 – 0.984) post-sanctuary), the improved survival rate still corresponds to an estimated decline of 0.5% per year (Gormley *et al*. 2012). Results of modelling efforts by Slooten and Davies (2012) also suggest continued population declines over the next 50 years if fisheries management practices remain the same (to 5,467 dolphins, Schaefer model; to 5,631 dolphins, Bayesian model).

Based on the available data and information, we conclude this demographic factor constitutes a **moderate risk** for SI Hector's dolphins. Updated models that reflect more recent abundance estimates and include a more complete representation of human-sources of mortality for SI Hector's dolphins would further improve the projections of future population trends.

4.3.2 Population Growth

Given an estimated lifespan of about 22 years, relatively late maturity (at 7-9 years), and low fecundity (0.165 to 0.25), Hector's dolphins are considered to have a low intrinsic population growth rate (Slooten 1991, Slooten and Lad 1991, Secchi and Fletcher 2004, Secchi *et al*. 2004b, Dawson 2009). Females may only produce four to seven calves over their lifetime. Based on simple Leslie matrix models, Slooten and Ladd (1991) estimated a maximum population growth rate of 0.018 to 0.049; whereas, Secchi and Fletcher (2004) estimated a much lower population growth rate of only 0.0065. Estimates for the survival rate of SI Hector's dolphins ≥ 1 year old have ranged from 0.77 to 0.89 (Slooten and Lad 1991, Slooten *et al*. 1992, Slooten and Dawson 1994, Cameron *et al*. 1999). Projections of population growth given estimated levels of human-caused mortality have varied depending on the modelling approach and the study population, but results are generally consistent in indicating a continuing population decline (Slooten and Dawson 2010, Slooten and Davies 2012). Essentially, the available information strongly suggests that population growth is too low to compensate for current mortality rates, and that mortality

needs to be reduced in order to allow populations around the South Island to recover from past declines due to bycatch (Slooten 2013).

Overall, we consider this demographic factor to constitute a **moderate risk** for SI Hector's dolphins.

4.3.3 Spatial Structure and Connectivity

Analyses of both mtDNA and microsatellite DNA indicate the existence of three distinct regional populations of SI Hector's dolphins - an east, west, and south coast population (Pichler *et al.* 1998, Pichler 2002, Hamner *et al.* 2012a). Each regional population is characterized by one or two high frequency mtDNA haplotypes (Figure 3), and hierarchical analyses of both mtDNA and microsatellite DNA data indicate strong genetic differentiation among the three regional populations (mtDNA F_{ST} = 0.321, p < 0.001; Phi $_{ST}$ = 0.395; microsatellite F_{ST} = 0.058, p < 0.001; (Hamner *et al*. 2012a). There appears to be additional genetic structuring on the south coast, as samples from Te Wæwæ Bay and Toetoe Bay, locations separated by only about 100 km of coastline, were significantly differentiated based on both mtDNA (F_{ST} = 0.136, p = 0.03) and microsatellite DNA (F_{ST} = 0.043, p = 0.005).

Estimated migration rates for males and females among the three main regional populations are low and appear to be asymmetrical (Pichler 2002, Hamner *et al.* 2012a). Based on mtDNA, Pichler (2002) estimated long-term migration rates of less than one female per generation among regions, except between the west and south coasts where female migration rates were estimated to be between 2.7 and 3.7 female migrants per generation. Based on analyses of both mtDNA and microsatellite DNA, there also appears to be a low level of male-mediated gene flow, with the highest exchange appearing to occur from the south coast to the east coast (Hamner *et al*. 2012a). This finding is consistent with results of assignment tests, which indicated very strong assignment of individual dolphins to the region where they were sampled but also identified five individuals that may have been produced by a migrant male and a resident female (Figure 5). Analysis of levels of genetic differentiation among sample locations within the larger regions suggests a stepping-stone model of gene flow in which there are low levels of migration between neighboring populations over distances shorter than 100 km and much more limited gene flow among the three larger regional populations (Pichler 2002; Hamner *et al.* 2012a). Hamner *et al.* (2012a) concluded that very rare migration events are facilitating gene flow across the roughly 100- 370 km distances separating the three larger regions. Overall, these findings are consistent with *a priori* expectations of low gene flow over larger spatial scales given the small estimated home ranges (typically 30 km - 60 km) and high degree of site fidelity observed in SI Hector's dolphins (Bejder and Dawson 2001, Bräger *et al.* 2002, Rayment *et al.* 2009a), and although longer-range movements (> 400 km) of SI Hector's

dolphins do appear to occur, at least on occasion, there is as yet no indication that such movements are associated with mating (Hamner *et al*. 2012b, Hamner *et al*. 2014a).

Firm conclusions based on these data with respect to extinction risk are difficult. The current distribution of SI Hector's as multiple populations with a low level of connectivity could potentially provide protection from local extirpation (for example, by a catastrophic event) while allowing for local adaptation, which could ultimately benefit long-term survival (Franklin 1980). Alternatively, restricted and asymmetrical dispersal among populations may mean there is very limited potential for one population to buffer against the loss of another local population and prevent further fragmentation (Pichler *et al.* 1998, Pichler 2001). The ongoing human-caused mortality and the slow population growth rate of SI Hector's dolphins are factors that favor this latter interpretation. Regardless of the correct interpretation, maintaining connectivity among regional populations will be an important component of conservation efforts for the SI Hector's dolphin (Hamner *et al*. 2012a). This is in turn implies that protecting the south coast population, which is estimated to contain only about 628 dolphins (95% CI = 301 – 1,311, Clement *et al*. 2011), is an essential component of such efforts.

In sum, we conclude that this demographic factor constitutes a **moderate risk** to SI Hector's dolphins.

4.3.4 Genetic Diversity

Relative to other dolphin species, genetic diversity of SI Hector's dolphins is low (Pichler and Baker 2000; Pichler 2002). Pichler and Baker (2000) reported haplotype (*h*) and nucleotide (π) diversity estimates of 0.35 and 0.30%, respectively, for ECSI Hector's dolphins (n=46) and 0.66 and 0.40% for WCSI Hector's dolphins (n= 47), which are low compared to previously reported estimates for other, abundant odontocetes (e.g., *h* = 0.70 - 0.92 and π > 1.0%). Diversity estimates based on mtDNA analyses by Hamner *et al*. (2012b) were somewhat higher for both the ECSI (*h* = 0.51, π= 0.39%) and WCSI (*h*=0.72, π= 0.49%, n= 154) populations, possibly as a consequence of larger sample sizes, but they are still relatively low. The low genetic diversity observed may reflect restricted gene flow among populations and a consequent increase in genetic drift within populations.

Based on an analysis of mtDNA samples for ECSI Hector's dolphins, Pichler and Baker (2000) reported a significant decline in mitochondrial diversity between historical samples from 1870-1987 (*h*=0.652 and π=0.0084, n=36) and more contemporary samples from 1988-1998 (*h*=0.350 and π=0.0030, n=46) and that the most common lineage had increased its representation from 58% to 80% between the two time periods. These authors suggest that the significant loss in genetic diversity reflects a recent population decline. A trend analysis of mtDNA diversity indicated full loss of diversity within the next 20 years (Pichler and Baker 2000).

Guidelines commonly cited and applied in conservation biology are that, in a finite population and ignoring other ecological considerations, a minimum effective population size of at least 50 individuals is required to prevent the harmful effects of inbreeding, and an effective population size of at least 500 individuals is required to prevent the accumulation of deleterious recessive alleles and maintain genetic diversity over hundreds of years (Franklin 1980, Soulé 1980, Gilpin and Soulé 1986, Allendorf *et al*. 1987). Other theoretical analyses, however, suggests that these thresholds are too low and that well over 1,000 breeding adults per generation may be necessary to avoid extinction by "mutational meltdown" over time periods of 100 or more generations (Lynch *et al.* 1995). Given that effective population size is often about 1/5 to 1/3 of a population's total size (Frankham 1995), a conservative effective population size for the total SI Hector's dolphin population (using 1/5 of the 95% CI abundance estimates, see Figure 6) could be roughly estimated as 2,051 to 4,497 dolphins. Because these rough estimates are well above the thresholds of 50, 500, and 1,000 associated with inbreeding, loss of genetic diversity, and mutational meltdown, we conclude that, the SI Hector's dolphins are not at high risk of extinction in the near-term due to its current genetic health.

Given the evidence of low and potentially declining genetic diversity, we conclude that this demographic factor constitutes a **moderate risk.**

4.4 Overall Extinction Risk for Maui's Dolphin

Concern over abundance and trends for Maui's dolphin has led to its classification as "nationally critical" under the New Zealand Threat Classification System, which is the most threatened status within this classification system (Baker *et al*. 2010). Maui's dolphin is also categorized as "critically endangered" on the IUCN's Red List.

Based on our review of the best available data and information, we conclude that Maui's dolphin is facing a **high risk** of extinction. Given the extremely small population size, reduced genetic diversity, low theoretical population growth rates, evidence of continued population decline, and the ongoing threats of bycatch, disease, mining and seismic disturbances, we conclude that this species is likely to become extinct. Our conclusion is consistent with previous risk assessments for Maui's dolphin, which have concluded this subspecies is facing an extremely high risk of extinction in the wild and will only recover if sources of anthropogenic mortality are eliminated (Slooten *et al*. 2006; MFish and DOC 2007b, Baker *et al*. 2010).

4.5 Overall Extinction Risk for SI Hector's Dolphin

Under the New Zealand Threat Classification System, Hector's dolphin has been formally classified as "Nationally Endangered", which is the second-most threatened status within this classification system (Baker *et al*. 2010). This classification was assigned based on criterion C(1/1), meaning that the number of mature individuals was estimated to be between 1,000 and 5,000 individuals and that there is an ongoing or predicted population decline of 50-70% due to existing threats over 3 generations (Townsend *et al.* 2008). Evidence of the declining trend was based on the population viability analysis of Slooten (2007a), which extrapolated the population size back to 1970 and estimated that the total Hector's dolphin population as of 2007 was only about 27% of what it was in 1970. The qualifier "Conservation Dependent" is also applied to SI Hector's dolphins, meaning that the subspecies is likely to move to the higher category of "Nationally Critical" if current management were to cease (Townsend *et al.* 2008, Baker *et al.* 2010). At the species level, Hector's dolphin is classified by the IUCN as Endangered under criterion A4d due to an ongoing and projected decline of greater than 50% over three generations (Reeves *et al*. 2013).

Although historical data are lacking, Slooten (2007a) estimated that the SI Hector's dolphin population has declined by about 73% between 1970 and 2007. Population viability analyses are also in general agreement that the SI Hector's dolphin will continue to decline unless bycatch mortality is drastically reduced (Davies *et al*. 2008, Slooten and Davies 2012, Slooten 2013). Projections by Slooten (2007) from an estimated total abundance of about 7,756 SI Hector's dolphins in 2007, suggest that SI Hector's dolphins would decline by about 31.7% (to 5,299 dolphins) by the year 2050 in the absence of additional bycatch reduction measures. For the much more data rich Banks Peninsula population, Gormley *et al.* (2012) estimated this particular population would continue to decline at a rate of about 0.5% per year despite significantly improved survival rates. Assuming an existing population abundance of about 14,849 dolphins (and range of 11,923 – 18,492 dolphins), a constant rate of decline of 0.5% per year for the subspecies would result in a 50% decline in the population in about 140 years and an 80% decline in about 320 years. This projection, however, is grossly over-simplified and not realistic. The actual rate of decline of the subspecies remains unclear given the very limited bycatch mortality data available. A trend analysis based on survey data is also confounded by the fact that surveys cover different portions of the range and have dramatically increased in their sophistication and geographical scope over time. Thus, a precise analysis of the rate of decline and projection of time to extinction given multiple threats and demographic considerations is not currently possible. Regardless of this lack of precision, the weight of the evidence points to a large historical decline and continued decline of this subspecies in the absence of additional, effective conservation measures. Current levels of bycatch are

contributing to this decline (Slooten and Davies 2012), and other threats, such as disease and tourism, are likely exacerbating the rate of decline and thereby contributing to the overall extinction risk of this subspecies.

Based on our review of the best available data, we conclude that the SI Hector's dolphin is at **moderate risk** of extinction. Given recent abundance estimates and evidence of a slowed rate of decline following expanded fisheries management measures, we find that this subspecies is not facing an imminent risk of extinction. However, the evidence of a historical decline and the projected decline for most populations combined with a low population growth rate; limited population connectivity; and the ongoing threats of bycatch, disease, and tourism; provide a strong indication that this subspecies will be at an elevated risk of extinction within the next several centuries.

REFERENCES

Abel, R. S., A. G. Dobbins, and T. Brown. 1971. *Cephalorhynchus hectori* subsp. *bicolor*. Sightings, capture, captivity. Investigations on Cetacea **3**: 171-179.

Allendorf, F. W., N. Ryman, and F. Utter. 1987. Genetics and fishery management: Past, present, and future. Pages 1-19 in Population Genetics and Fishery Management. N. Ryman and F. Utter, eds. University of Washington Press, Seattle, WA.

Baird, S. J., and E. Bradford. 2000. Estimation of the Hector's dolphin bycatch from the inshore fisheries, 1997/98 fishing year. New Zealand Department of Conservation.

Baker, A. N. 1978. The status of Hector's dolphin, *Cephalorynchus hectori* (Van Beneden), in New Zealand waters. Report of the International Whaling Commission **28**: 331-334.

Baker, A. N., A. N. H. Smith, and F. B. Pichler. 2002. Geographical variation in Hector's dolphin: Recognition of new subspecies of *Cephalorhynchus hectori*. Journal of the Royal Society of New Zealand **32**: 713-727.

Baker, C. S., B. L. Chilvers, R. Constantine, S. DuFresne, R. H. Mattlin, A. van Helden, and R. Hitchmough. 2010. Conservation status of New Zealand marine mammals (suborders Cetacea and Pinnipedia), 2009. New Zealand Journal of Marine and Freshwater Research **44**: 101-+.

Baker, C. S., R. M. Hamner, J. Cooke, D. Heimeier, M. Vant, D. Steel, and R. Constantine. 2013. Low abundance and probable decline of the critically endangered Maui's dolphin estimated by genotype capture-recapture. Animal Conservation **16**: 224-233.

Beentjes, M. P., B. Bull, R. J. Hurst, and N. W. Bagley. 2002. Demersal fish assemblages along the continental shelf and upper slope of the east coast of the South Island, New Zealand. New Zealand Journal of Marine and Freshwater Research **36**:1 97-223.

Bejder, L., A. Samuels, H. Whitehead, and N. Gales. 2006a. Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. Animal Behaviour **72**:1149-1158.

Bejder, L., A. Samuels, H. Whitehead, N. Gales, J. Mann, R. Connor, M. Heithaus, J. Watson-Capps, C. Flaherty, and M. Krutzen. 2006b. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conservation Biology **20**:1791-1798.

Bejder, L., A. Samuels, J. Mann, H. Whitehead, N. Gales, R. Connor, M. Heithaus, J. Watson-Capps, and C. Flaherty. 2006c. Manage it or lose it: Reproductive success of female bottlenose dolphins is negatively correlated with exposure to dolphin-watch vessels. International Whaling Commission Scientific Committee, St. Kitts and Nevis, West Indies.

Bejder, L., and S. Dawson. 2001. Abundance, residency, and habitat utilisation of Hector's dolphins (*Cephalorhynchus hectori*) in Porpoise Bay, New Zealand. New Zealand Journal of Marine and Freshwater Research **35**: 277-287.

Bejder, L., S. M. Dawson, and J. A. Harraway. 1999. Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. Marine Mammal Science **15**: 738-750.

Bird, R., and M. Palka. 2013. Preventing an extinction event: Is New Zealand's management response enough to save the world's rarest marine dolphin? , IWC Scientific Committee.

Brager, S. 1998b. Feeding associations between white-fronted terns and Hector's dolphins in New Zealand. Condor **100**:560-562.

Bräger, S. 1999a. Association patterns in three populations of Hector's dolphin, *Cephalorhynchus hectori*. Canadian Journal of Zoology **77**:13-18.

Bräger, S., J. A. Harraway, and B. F. J. Manly. 2003. Habitat selection in a coastal dolphin species (*Cephalorhynchus hectori*). Marine Biology **143**:233-244.

Bräger, S., S. M. Dawson, E. Slooten, S. Smith, G. S. Stone, and A. Yoshinaga. 2002. Site fidelity and along-shore range in Hector's dolphin, an endangered marine dolphin from New Zealand. Biological Conservation **108**:281-287.

Buckland, S. J., D. J. Hannah, J. A. Taucher, E. Slooten, and S. Dawson. 1990. Polychlorinated dibenzo-p-dioxins and dibenzofurans in New Zealand's Hector's dolphin. Chemosphere **20**:1035-1042.

Burkhart, S. M., and E. Slooten. 2003. Population viability analysis for Hector's dolphin (*Cephalorhynchus hectori*): A stochastic population model for local populations. New Zealand Journal of Marine and Freshwater Research **37**:553-566.

Cameron, C., R. Barker, D. Fletcher, E. Slooten, and S. Dawson. 1999. Modelling survival of Hector's dolphins around Banks Peninsula, New Zealand. Journal of Agricultural, Biological and Environmental Statistics **4**:126-135.

Cawthorn, M. W. 1988. Recent observations of Hector's dolphin, *Cephalorhynchus hectori*, in New Zealand. Report of the International Whaling Commission. Special Issue 9: 303-314.

Clement, D., Rob Mattlin, and Leigh Torres. 2011. Abundance, distribution and productivity of Hector's (and Maui's) dolphins. MFISH. Final Research Report. 50 pages.

Constantine, R. 1999. Effects of tourism on marine mammals in New Zealand. New Zealand Department of Conservation.

Currey, R. J. C., L. J. Boren, B. R. Sharp, and D. Peterson. 2012. A risk assessment of threats to Maui's dolphins. Ministry for Primary Industries and Department of Conservation, Wellington, NZ.

Currey, R. J. C., L. J. Boren, B. R. Sharp, F. N. Thompson, and Y. Richard. 2013. Spatially-explicit semi-quantitative risk assessment of threats to Maui's dolphins (*Cephalorhynchus hectori maui*). Pages 53-54 Twentieth Biennial Conference on the Biology of Marine Mammals, Dunedin, New Zealand.

Davies, N., R. Bian, P. Starr, P. Lallemand, D. Gilbert, and J. McKenzie. 2008. Risk analysis for Hector's dolphin and Maui's dolphin subpopulations to commercial set net fishing using a temporal-spatial age-structured model. Ministry of Fisheries, Wellington, New Zealand. NIWA Report for New Zealand Ministry of Fisheries.

Davies, N., R. Bian, P. Starr, P. Lallemand, J. McKenzie, D., Gilbert. 2007. Hector's and Maui's dolphin—risk analysis. Aquatic Environment Working Group 17 September 2007, Ministry of Fisheries, Wellington.

Dawson, S. M. 1988a. The high frequency sounds of free-ranging Hector's dolphins, *Cephalorhynchus hectori*. Report of the International Whaling Commission **Special Issue 9**:339-344.

Dawson, S. M. 1991a. Clicks and communication: The behavioural and social contexts of Hector's dolphin vocalizations. Ethology **88**:265-276.

Dawson, S. M. 1991b. Incidental catch of Hector's dolphin in inshore gillnets. Marine Mammal Science **7**:283-295.

Dawson, S. M. 1998. Pingers, porpoises and power: Uncertainties with using pingers to reduce bycatch of small cetaceans. Biological Conservation **84**:141-146.

Dawson, S. M. 2009. Cephalorhynchus dolphins: *C. heavisidii, C. eutropia, C. hectori*, and *C. commersonii*. Pages 191-196 *in* W. F. Perrin, B. Wursig, and J. G. M. Thewissen, editors. Encyclopedia of Marine Mammals. Academic Press, San Diego.

Dawson S., D. Fletcher, E. Slooten 2013. Habitat use and conservation of an Endangered dolphin. Endangered Species Research **21**: 45–54.

Dawson, S., E. Slooten, S. Dufresne, P. Wade, and D. Clement. 2004. Small-boat surveys for coastal dolphins: Line-transect surveys for Hector's dolphins (*Cephalorhynchus hectori*). Fishery Bulletin **102**:441-451.

Dawson, S. M., and E. Slooten. 1988b. Hector's dolphin, *Cephalorhynchus hectori*: Distribution and abundance. Report of the International Whaling Commission **Special Issue 9**:315-324.

Dawson, S. M., and E. Slooten. 1993. Conservation of Hector's dolphins: The case and process which led to establishment of the Banks Peninsula Marine Mammal Sanctuary. Aquatic Conservation: Marine and Freshwater Ecosystems **3**:207-221.

Dawson, S. M., and E. Slooten. 2005. Management of gillnet bycatch of cetaceans in New Zealand. Journal of cetacean Research and Management **7**:59.

Dawson, S., F. Pichler, E. Slooten, K. Russell, and C. S. Baker. 2001b. The North Island Hector's dolphin is vulnerable to extinction. Marine Mammal Science **17**:366-371.

Derville S., R. Constantine, C. S. Baker, M. Oremus, L. G. Torres. 2016. Environmental correlates of nearshore habitat distribution by the critically endangered Maui dolphin. Marine Ecology Progress Series **551**: 261–275.

DOC. 2012. 2012 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations. Department of Conservation. Wellington. 30pp.

DOC. 2013. 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations. Department of Conservation. Wellington. 36 pp.

DOC and MFish. 1994. Review of the Banks Peninsula Marine Mammal Sanctuary: a paper for public comment. Department of Conservation of Ministry of Agriculture and Fisheries, Christchurch, New Zealand, Canterbury Conservancy miscellaneous report series no. 3.

Du Fresne, S. 2010. Distribution of Maui's dolphin (*Cephalorhynchus hectori maui*) 2000-2009. Department of Conservation, Wellington, New Zealand.

Du Fresne, S., S. Dawson, and E. Slooten. 2001a. Line-transect survey of Hector's dolphin abundance between Timaru and Long Point, and effect of attraction to survey vessel. New Zealand Department of Conservation.

Faustino, C., W. Rayment, E. Slooten, S. Dawson, and M. Mackenzie. 2013. Animal distribution and spatial management: Hector´s dolphin populations off the South Island, New Zealand. Page 67 Twentieth Biennial Conference on the Biology of Marine Mammals, Dunedin, New Zealand.

Ferreira, S. M., and C. C. Roberts. 2003. Distribution and abundance of Maui's dolphins (*Cephalorhynchus hectori maui*) along the North Island west coast, New Zealand. New Zealand Department of Conservation.

Franklin, I. R. 1980. Evolutionary change in small populations.*in* M. E. Soule and B. Wilcox, editors. Conservation Biology: An Evolutionary-Ecological Perspective. Sinauer, Sunderland, Massachusetts.

Frankham, R. 1995. Effective population-size adult-population size ratios in wildlife—a review. Genetical Research **66**: 95-107

Fujise, Y., K. Honda, R. Tatsukawa, and S. Mishima. 1988. Tissue distribution of heavy metals in Dall's porpoise in the northwestern Pacific. Marine Pollution Bulletin **19**: 226-230.

Gilpin, M. E., and M. E. Soulé. 1986. Minimum Viable Populations: Processes of Species Extinction. Pages 19-34 in M. E. Soulé, ed. Conservation Biology: The Science of Scarcity and Diversity. Sunderland: Sinauer & Associates, Massachusetts.

Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M.P., Swift, R. and Thompson, D. 2003. A review of the effects of seismic surveys on marine mammals. Marine Technology Society Journal **37**:16-34.

Gormley, A. M. 2009. Population modelling of Hector's dolphins. PhD thesis. Otago University, Dunedin, New Zealand.

Gormley, A. M., E. Slooten, S. Dawson, R. J. Barker, W. Rayment, S. du Fresne, and S. Brager. 2012. First evidence that marine protected areas can work for marine mammals. Journal of Applied Ecology **49**:474-480.

Green, E., C. Charteris, and J. Rodda. 2007. Te Waewae Bay Hector's dolphins: Abundance, Distribution, and Threats. Department of Conservation, New Zealand.

Gregory, M.R. 2009. Environmental implications of plastic debris in marine settings— entanglement, ingestion, smothering, hangers-on, hitch-hiking, and alien invasions. Philosophical Transactions of the Royal Society B **364**: 2013–2025.

Hamner, R. M., D. Steel, R. Constantine, M. Morrissey, M. Ogle, J. Weir, C. Olavarría, A. Baxter, W. Arlidge, L. Boren, and C. S. Baker. 2016. Local population structure and abundance of Hector's dolphins off Kaikoura – 2014 and 2015. Report to the New Zealand Department of Conservation – 6 March 2016

Hamner, R. M., F. B. Pichler, D. Heimeier, R. Constantine, and C. S. Baker. 2012a. Genetic differentiation and limited gene flow among fragmented populations of New Zealand endemic Hector's and Maui's dolphins. Conservation Genetics **13**: 987-1002.

Hamner, R. M., M. Oremus, M. Stanley, P. Brown, C. S. Baker, and R. Constantine. 2012b. Estimating the abundance and effective population size of Maui's dolphins using microsatellite genotypes in 2010–11, with retrospective matching to 2001–07. Department of Conservation, Auckland.

Hamner, R. M., P. Wade, M. Oremus, M. Stanley, P. Brown, R. Constantine, and C. Scott Baker. 2014b. Critically low abundance and limits to human-related mortality for the Maui's dolphin. Endangered Species Research **26**: 87-92.

Hamner, R. M., R. Constantine, M. Oremus, M. Stanley, P. Brown, and C. Scott Baker. 2014a. Long-range movement by Hector's dolphins provides potential genetic enhancement for critically endangered Maui's dolphin. Marine Mammal Science **30**: 139-153.

Hamner, R.M., R. Constantine, R. Mattlin, R. Waples, and C. S. Baker. 2013. Genotype capture-recapture estimates of abundance and effective population size of Hector's dolphins in Cloudy Bay, New Zealand. SC/65a/SM07. 65th meeting of the International Whaling Commission Scientific Committee, Jeju, South Korea.

IUCN. 2012. Actions to avert the extinctions of rare dolphins: Maui's dolphins, Hector's dolphins, Vaquita and South Asian river dolphins. Motion 35, adopted at the IUCN World Conservation Congress, Jeju, 2012. (http://portals.iucn.org/2012motions/).

IWC. 2016. Report of the scientific committee of the International Whaling Commission. 66/Rep01/Annex M. Bled., Slovenia, June 7-19, 2016.

Jepson, P. D., P. M. Bennett, R. Deaville, C. R. Allchin, J. R. Baker, and R. J. Law. 2005. Relationships between polychlorinated biphenyls and health status in harbor porpoises

(*Phocoena phocoena*) stranded in the United Kingdom. Environmental Toxicology and Chemistry **24**: 238-248.

Kuiken, T., P. M. Bennett, C. R. Allchin, J. K. Kirkwood, J. R. Baker, C. H. Lockyer, M. J. Walton, and M. C. Sheldrick. 1994. PCBs, cause of death and body condition in harbour porpoises (*Phocoena phocoena*) from British waters. Aquatic Toxicology **28**: 13-28.

Laist, D. W. 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: J. M. Coe and D. B. Rogers, eds. Marine debris, sources, impacts, and solutions pp. 99–139. New York, NY. Springer-Verlag.

Lynch, M. M. Lynch, J. Conerya, and R. Burger. 1995. Mutation Accumulation and the Extinction of Small Populations. American Naturalist **146**: 489-518

Mace, G. M., N. J. Collar, K. J. Gaston, C. Hilton-Taylor, H. R. Akçakaya, N. Leader-Williams, E. J. Milner-Gulland, and S. N. Stuart. 2008. Quantification of extinction risk: IUCN's system for classifying threatened species. Conservation Biology **22**: 1424-1442.

Mace, G. M., and R. Lande. 1991. Assessing extinction threats: Toward a reevaluation of IUCN Threatened species categories. Conservation Biology **5**:148-157.

MacKenzie, D., and D. Clement. 2014. Abundance and Distribution of ECSI Hector's dolphin. New Zealand Aquatic Environment and Biodiversity Report No. 123. Ministry for Primary Industries. Wellington, New Zealand.

MacKenzie, D., and D. Clement. 2016. Abundance and Distribution of WCSI Hector's dolphin. New Zealand Aquatic Environment and Biodiversity Report No. 168. Ministry for Primary Industries. Wellington, New Zealand.

Martien, K.K., B.L Taylor, E. Slooten, and S. Dawson. 1999. A sensitivity analysis to guide research and management for Hector's dolphin. Biological Conservation **90**:183–191.

Martinez, E. 2010. Responses of South Island Hector's dolphins (Cephalorhynchus hectori hectori) to vessel activity (including tourism operations) in Akaroa Harbour, Banks Peninsula, New Zealand: a thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Marine Biology at Massey University, Auckland, New Zealand.

Martinez, E., M. B. Orams, M. D. M. Pawley, and K. A. Stockin. 2012. The use of auditory stimulants during swim encounters with Hector's dolphins (*Cephalorhynchus hectori hectori*) in Akaroa Harbour, New Zealand. Marine Mammal Science **28**: E295-E315.

Miller, E., C. Lalas, S. Dawson, H. Ratz, and E. Slooten. 2013. Hector's dolphin diet: The species, sizes and relative importance of prey eaten by *Cephalorhynchus hectori*, investigated using stomach content analysis. Marine Mammal Science **29**:606-628.

MFish. 2008. Minister's Decision Letter on Fisheries Measures. http://www.fish.govt.nz/en-nz/Consultations/Archive/2008/Hectors+dolphins/Decisions.htm?wbc_purpose=Basic&WBCMODE=Presentation.

MFish and DOC. 2007a. Hector's Dolphin Threat Management Discussion Document. Ministry of Fisheries and Department of Conservation. April 2007.

MFish and DOC. 2007b. Hector's and Maui's Dolphin Threat Management Pan. Draft for Public Consultation. Ministry of Fisheries and Department of Conservation. August 2007.

MMPR. 1992. Marine Mammals Protection Regulations. http://www.legislation.govt.nz/regulation/public/1992/0322/latest/DLM168286.html?search=ts_act%40bill%40regulation%40deemedreg_marine+mammals_resel_25_a&p=1

MPI. 2011a. Minister's decision letter on management measures for Hector's and Maui's dolphins. (http://www.fish.govt.nz).

MPI. 2011b. Final Advice Paper on Reconsideration of Measures to Manage Fishing Related Threats to Maui's and Hector's Dolphins. (http://www.fish.govt.nz).

MPI and DOC. 2013. http://mpi.govt.nz/news-and-resources/consultations/mauis-dolphin-portion-hectors-mauis-dolphin-threat-management-plan/.

O'Grady, J. J., B. W. Brook, D. H. Reed, Jonathan D. Ballou, D. W. Tonkyn, R. Frankham. 2006. Realistic levels of inbreeding depression strongly affect extinction risk in wild populations. Biological Conservation 133: 42-51.

O'Hara, T. M., and T. J. O'Shea. 2001. Toxicology. Pages 471-520 *in* L. A. Dierauf and F. M. D. Gullands, editors. CRC Handbook of Marine Mammal Medicine. CRC Press, Boca Raton, Florida.

Oremus, M., R. M. Hamner, M. Stanley, P. Brown, C. S. Baker, and R. Constantine. 2012. Distribution, group characteristics and movements of the critically endangered Maui's dolphin *Cephalorhynchus hectori maui*. Endangered Species Research **19**: 1-10.

Pichler, F. B. 2002. Genetic assessment of population boundaries and gene exchange in Hector's dolphin. New Zealand Department of Conservation.

Pichler, F. B. 2001. Population structure and genetic variation in Hector's dolphin (Cephalorhynchus hectori). Ph.D. Thesis, University of Auckland; Auckland, New Zealand.

Pichler, F. B. and C. S. Baker. 2000. Loss of genetic diversity in the endemic Hector's dolphin due to fisheries-related mortality. Proceedings of the Royal Society of London Series B Biological Sciences **267**: 97-102.

Pichler, F. B., D. Robineau, R. N. P. Goodall, M. A. Meyer, C. Olivarria, and C. S. Baker. 2001. Origin and radiation of southern hemisphere coastal dolphins (genus *Cephalorhynchus*). Molecular Ecology **10**:2215-2223.

Pichler, F. B., E. Slooten, and S. M. Dawson. 2003. Hector's dolphins and fisheries in New Zealand: A species at risk. Pages 153-173 *in* N. Gales, M. Hindell, and R. Kirkwood, editors. Marine Mammals: Fisheries, Tourism and Management Issues. CSIRO Publishing, Melbourne.

Pichler, F. B., S. M. Dawson, E. Slooten, and C. S. Baker. 1998. Geographic isolation of Hector's dolphin population described by mitochondrial DNA sequences. Conservation Biology **12**: 676-682.

Rayment, W., D. Clement, S. Dawson, E. Slooten, and E. Secchi. 2011b. Distribution of Hector's dolphin (*Cephalorhynchus hectori*) off the west coast, South Island, New Zealand, with implications for the management of bycatch. Marine Mammal Science **27**: 398-420.

Rayment, W., S. Dawson, and E. Slooten. 2010b. Seasonal changes in distribution of Hector's dolphin at Banks Peninsula, New Zealand: Implications for protected area design. Aquatic Conservation: Marine and Freshwater Ecosystems **20**: 106-116.

Rayment, W., S. Dawson, E. Slooten, S. Brager, S. D. Fresne, and T. Webster. 2009a. Kernel density estimates of alongshore home range of Hector's dolphins at Banks Peninsula, New Zealand. Marine Mammal Science **25**: 537-556.

Rayment, W., S. Dawson, E. Slooten, and S. Childerhouse. 2006. Offshore distribution of Hector's dolphin at Banks Peninsula. DOC Research and Development Series 232. New Zealand Department of Conservation, Wellington, New Zealand.

Rayment, W., S. Dawson, S. Scali, and E. Slooten. 2011a. Listening for a needle in a haystack: Passive acoustic detection of dolphins at very low densities. Endangered Species Research **14**: 149-156.

Rayment, W. and T. Webster. 2009c. Observations of Hector's dolphins (*Cephalorhynchus hectori*) associating with inshore fishing trawlers at Banks Peninsula, New Zealand. New Zealand Journal of Marine and Freshwater Research **43**: 911-916.

Reeves, R.R., S.M. Dawson, T.A. Jefferson, L. Karczmarski, K. Laidre, G. O'Corry-Crowe, L. Rojas-Bracho, E.R. Secchi, E. Slooten, B.D. Smith, J.Y. Wang, and K. Zhou. 2013. IUCN

Assessment. (Assessed on 2008-07-01; downloaded on June 22, 2016, from http://www.iucnredlist.org/details/full/4162/0

Rodda, J. L. 2014. Analysis and geovisualization of Hector's dolphin abundance and distribution patterns in space and time. Ph.D. Thesis. University of Otago. http://hdl.handle.net/10523/6320.

Roe, W. D., L. Howe, E. J. Baker, L. Burrows, and S. A. Hunter. 2013. An atypical genotype of *Toxoplasma gondii* as a cause of mortality in Hector's dolphins (*Cephalorhynchus hectori*). Veterinary Parasitology **192**: 67-74.

Russell K. 1999. The North Island Hector's dolphin: A species in need of conservation. M.Sc. Thesis, University of Auckland, Auckland.

Schaefer M. B. 1954. Some aspects of the dynamics of populations important to the management of commercial fisheries. Bulletin of the Inter-American Tropical Tuna Commission **1**: 27–56.

Schwacke, L. H., E. O. Voit, L. J. Hansen, R. S. Wells, G. B. Mitchum, A. A. Hohn, and P. A. Fair. 2002. Probabilistic risk assessment of reproductive effects of polychlorinated biphenyls on bottlenose dolphins (*Tursiops truncatus*) from the southeast United States coast. Environmental Toxicology and Chemistry **21**: 2752-2764.

Secchi, E. R. and D. Fletcher. 2004. Assessing the effects of fishing bycatch on the population growth and viability of Hector's dolphins. International Whaling Commission Scientific Committee, Sorrento, Italy.

Secchi, E. R., D. Fletcher, D. Clement, and D. Neale. 2004a. Estimation of the overlap of Hector's dolphins with gillnet fisheries as a tool to improve estimates of bycatch mortality rate. International Whaling Commission Scientific Committee, Sorrento, Italy.

Secchi, E. R., E. Slooten, and S. Dawson. 2004b. Gillnet-caught Hector's dolphins (*Cephalorhynchus hectori*): Gender, reproductive status and reproductive characteristics of females. International Whaling Commission Scientific Committee, Sorrento, Italy.

Slooten, E. 1991. Age, growth, and reproduction in Hector's dolphins. Canadian Journal of Zoology **69**: 1689-1700.

Slooten, E. 1994. Behavior of Hector's dolphin: Classifying behavior by sequence analysis. Journal of Mammalogy **75**: 956-964.

Slooten, E. 2007a. Conservation management in the face of uncertainty: Effectiveness of four options for managing Hector's dolphin bycatch. Endangered Species Research **3**: 169-179.

Slooten, E. 2007b. Criticism is unfounded: Reply to Middleton et al. (2007). Endangered Species Research **3**: 335-339.

Slooten, E. 2013. Effectiveness of area-based management in reducing bycatch of the New Zealand dolphin. Endangered Species Research **20**: 121-130.

Slooten, E. 2014. Effectiveness of 2013 changes to marine protected areas for New Zealand dolphin. Paper SC/65/SM08 Scientific Committee of the International Whaling Commission, Bled, Slovenia.

Slooten, E. 2015a. Effectiveness of partial protection for Maui's dolphin. Paper SC/66a/SM/12 Scientific Committee of the International Whaling Commission, San Diego, USA.

Slooten, E. 2015b. How many Hector's dolphins off the east coast of the South Island. Paper SC/66a/SM/15 Scientific Committee of the International Whaling Commission, San Diego, USA.

Slooten, E. and F. Lad. 1991. Population biology and conservation of Hector's dolphins. Canadian Journal of Zoology **69**: 1701-1707.

Slooten, E. and N. Davies. 2012. Hector's dolphin risk assessments: Old and new analyses show consistent results. Journal of the Royal Society of New Zealand **42**: 49-60.

Slooten, E. and S. M. Dawson. 1988. Studies on Hector's dolphin, *Cephalorhynchus hectori*: A progress report. Report of the International Whaling Commission Special Issue **9**: 325-338.

Slooten, E. and S. M. Dawson. 1994. Hector's dolphin, *Cephalorhynchus hectori* (van Beneden, 1881). Pages 311-333 *in* S. H. Ridway and S. R. Harrison, editors. Handbook of Marine Mammals. Academic Press, London.

Slooten, E. and S. M. Dawson. 2008. Effectiveness of new protection measures for Hector's dolphin. International Whaling Commission Scientific Committee, Santiago, Chile.

Slooten, E. and S. M. Dawson. 2010. Assessing the effectiveness of conservation management decisions: Likely effects of new protection measures for Hector's dolphin (*Cephalorhynchus hectori*). Aquatic Conservation: Marine and Freshwater Ecosystems **20**: 334-347.

Slooten, E. and S. M. Dawson. 2016. Hector's and Maui dolphin bycatch 1985-2015. Paper SC/66b/SM15 Scientific Committee of the International Whaling Commission, Bled, Slovenia.

Slooten, E., S. M. Dawson, and F. Lad. 1992. Survival rates of photographically identified Hector dolphins from 1984 to 1988. Marine Mammal Science **8**: 327-343.

Slooten, E., S. M. Dawson, and H. Whitehead. 1993. Associations among photographically identified Hector's dolphins. Canadian Journal of Zoology **71**:2311-2318.

Slooten, E., S. M. Dawson, and W. J. Rayment. 2004. Aerial surveys for coastal dolphins: Abundance of Hector's dolphins off the South Island west coast, New Zealand. Marine Mammal Science **20**: 477-490.

Slooten, E., S. M. Dawson, W. Rayment, and S. Childerhouse. 2005. Distribution of Maui's dolphin, Cephalorhynchus hectori maui. New Zealand Fisheries Assessment Report **28**: 21.

Slooten, E., S. M. Dawson, W. Rayment, and S. Childerhouse. 2006a. A new abundance estimate for Maui's dolphin: What does it mean for managing this critically endangered species? Biological Conservation **128**: 576-581.

Slooten, E., W. Rayment, and S. Dawson. 2006b. Offshore distribution of Hector's dolphins at Banks Peninsula, New Zealand: Is the Banks Peninsula Marine Mammal Sanctuary large enough? New Zealand Journal of Marine and Freshwater Research **40**: 333-343.

Soulé, M. E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-169 in M. E. Soule and A. Wilcox, Eds. Conservation biology: an evolutionary-ecological perspective. Sinauer Associates, Sunderland, MA

Starr, P. and A. Langley. 2000. Inshore Fishery Observer Programme for Hector's dolphins in Pegasus Bay. Canterbury Bight, 1997/98. Report to DOC. Department of Conservation, Wellington. 27 pp.

Stockin, K. A., R. J. Law, W. D. Roe, L. Meynier, E. Martinez, P. J. Duignan, P. Bridgen, and B. Jones. 2010. PCBs and organochlorine pesticides in Hector's (*Cephalorhynchus hectori hectori*) and Maui's (*Cephalorhynchus hectori maui*) dolphins. Marine Pollution Bulletin **60**: 834-842.

Stone, G. S. and A. Yoshinaga. 2000. Hector's dolphin *Cephalorhynchus hectori* calf mortalities may indicate new risks from boat traffic and habituation. Pacific Conservation Biology **6**: 162-170.

Stone, G. S., J. Brown, and A. Yoshinaga. 1995. Diurnal movement patterns of Hectors dolphin as observed from clifftops. Marine Mammal Science **11**: 395-402.

Stone, G. S., L. Cavagnaro, A. Hutt, S. Kraus, K. Baldwin, and J. Brown. 2000. Reactions of Hector's dolphins to acoustic gillnet pingers. New Zealand Department of Conservation.

Thompson, K.F. 2012. Maui's and mining: a review of marine mineral mining activity on the west coast of New Zealand and its potential impacts. Report to the Department of Conservation Auckland Area Office, March 2012. 44p.

Townsend, Andrew J., Peter J. de Lange, Clinton A.J. Duffy, Colin M. Miskelly, Janice Molloy and David A. Norton. 2008. New Zealand Threat Classification System Manual. Science and Technical Publishing. Department of Conservation. Wellington, New Zealand. 36 pp.

Wade, P.R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Marine Mammal Science **14**: 1–37.

Wade, P.R., R.M. Hamner, R. Constantine, and C.S. Baker. 2012. The Potential Biological Removal (PBR) and probability of decline for Maui's dolphin. pp. 28-32 In: Currey, R.J.C., Boren, L.J., Sharp, B.R. and Peterson, D. 2012. A risk assessment of threats to Maui's dolphins. Ministry for Primary Industries and Department of Conservation, Wellington. 51 pp.

Waples, R.S.; C. Do. 2008. LDNe: a program for estimating effective population size from data on linkage disequilibrium. Molecular Ecology Resources **8**: 753–756.

Webster, T. A., S. M. Dawson, and E. Slooten. 2009. Evidence of sex segregation in Hector's dolphin (*Cephalorhynchus hectori*). Aquatic Mammals **35**: 212-219.

Wells, R. S., V. Tornero, A. Borrell, A. Aguilar, T. K. Rowles, H. L. Rhinehart, S. Hofmann, W. M. Jarman, A. A. Hohn, and J. C. Sweeney. 2005. Integrating life-history and reproductive success data to examine relationships with organochlorine compounds for bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. Science of the Total Environment **349**: 106-119.