Hector's Dolphins, *Cephaloryhnchus hectori hectori*: A Management Plan to Increase Populations via Increased Protective Legislature

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Executive Summary

Hector's dolphins (*Cephalorhynchus hectori*) are the only cetacean endemic to New Zealand. The South Island subspecies (*C. hectori hectori*) has an estimated population size of 7,270 individuals and has been listed as Endangered on the IUCN red list since 2000. The largest threat to Hector's dolphins is gillnet mortalities – it's estimated that 63% of mortalities are caused by fisheries bycatch. The life history of the dolphins indicates that they cannot reproduce quickly enough to replace the individuals lost to bycatch. Current rates of gillnet mortality must be decreased by at least 75% for Hector's dolphins to recover. This plan is designed increase populations of Hector's dolphins by decreasing gillnet mortalities to a sustainable level through legislation. Paramount to this goal are increasing the size and number of protected areas and increasing gillnet restrictions across the range of Hector's dolphins. The offshore distribution of Hector's dolphins depends on the bathymetry of the area, and thus management areas should be evaluated individually to best protect local populations.

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Objective 2: Increase protected habitat across the South Island, focusing on areas with high density populations.

Objective 3: Reduce fishery bycatch mortalities across the nonprotected South Island populations by 75%.

Introduction

Hector's dolphins (*Cephalorhynchus hectori hectori*) are an endemic New Zealand cetacean currently experiencing a decline due primarily to gillnet entanglement (Department of Conservation & Ministry of Fisheries 2007a; Slooten et al. 2006a). This plan will outline steps towards managing a sustainable level of bycatch of *C. hectori hectori* around the South Island. The most effective means of increasing survivability of Hector's dolphins is by creating Marine Mammal Sanctuaries around high-density populations and by increasing the protective legislature outside of protected areas (Slooten et al. 2006a; Slooten & Dawson 2010). The goal of this plan is not to eliminate or harm the fisheries industry around the South Island in any way, but rather to create a system in which gillnet bycatch of Hector's dolphins is sustainable for the population.

Natural History

Taxonomy

Hector's dolphins (*Cephalorhynchus hectori*) are the the only cetacean endemic to New Zealand. There are two recognized subspecies: Maui's dolphin (*Cephalorhynchus hectori maui*) and Hector's dolphin (*Cephaloryhnchus hectori hectori*) (Baker et al. 2002). Maui's dolphins are found only on the coast of the North Island, and are listed by the IUCN Red List (Reeves et al. 2013) as critically endangered with a total population estimate of 111 individuals (Slooten et al. 2006b). Hector's dolphin is found along the north, east, and west coasts of the South Island and, while more numerous, are still listed as endangered by the IUCN Red List (Reeves et al. 2013).

Species Description

The smallest of all dolphin species, Hector's dolphins grow to a maximum length of 1.6 meters (Slooten 1991; Webster et al. 2010) and weigh a maximum of 60kg (Slooten 1991). There is a slight incidence of sexual dimorphism, with females being slightly longer and heavier than males (Webster et al. 2009). Hector's dolphins display the typical cetacean fusiform body shape, although they have no discernible beak. The dorsal fin is rounded, with a convex trailing edge and an undercut rear margin (Gormley et al. 2005; Webster et al. 2010). Hector's dolphins have a pale grey body, though their dorsal fin, flippers, flukes, and face mask are all dark grey to black (Figure 1). The throat and belly are white in color (Gormley et al. 2005).

Figure 1: Illustration of an adult Hector's dolphin. (Source: swisscetaceansociety.org)

Hector's dolphins are generalist feeders, with prey from throughout the water column. Red cod (*Pseudophyscis bachus*), ahuru (*Auchenoceros punctatus*), arrow squid (*Nototodarus* sp.), sprat (*Sprattus* sp.), sole (*Peltorhamphus* sp.), and stargazer (*Crapatalus* sp.) are the most common prey, likely due to abundance, and account for 75% of consumed diet by mass (Miller et al. 2013). The diet of Hector's dolphins is strongly influenced by their distribution.

Historically, most individuals have been seen within 4 nautical miles of shore (Dawson et al. 2004) but recent evidence suggests that water depth is a more contributing factor than distance from shore (Slooten et al. 2006a). Hector's dolphins are typically found in waters less than 14m in depth (Bräger et al. 2003). The bathymetry of the west coast may have contributed to the confusion of selection factors – the continental shelf only extends about 5 nautical miles offshore, so most suitable habitat isn't further than that (Dawson et al. 2004). Recent research on the east coast, where the continental shelf extends past 15 nautical miles offshore, indicates that Hector's dolphins are distributed evenly despite distance from shore (Slooten et al. 2006a). Hector's dolphins are distributed across the west, north, and east coasts of the South Island (Figure 2) (Dawson et al. 2004; Slooten et al. 2004; Slooten & Dawson 2010).

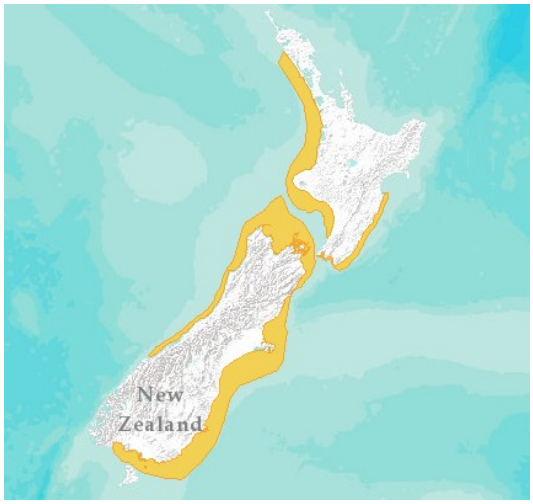

Figure 2: Range map of Hector's dolphins. The North Island subspecies is *C. hectori maui* and the South Island subspecies is *C. hectori hectori*. (Source: IUCN 2013)

Life History Strategy

Hector's dolphins exhibit a reproductive strategy typical of most cetaceans, in that they are relatively long-lived and produce few young over their lives. It takes 7 years for females to reach sexual maturity (5 for males) and a female can only calve once every 2 or 3 years (Slooten 1991; Slooten et al. 2000). Each birth results in 1 calf. Calves will stay with their mother for up to 12 months. The oldest known individual was 23 years of age, although females typically live to only 19 years of age and males live until they are 20 (Slooten 1991;Webster et al. 2009). Combined, these factors result in any female birthing a maximum of six young in her lifetime (Slooten 1991). The limiting female reproductive strategy results in a population with very slow growth, with a maximum possible growth rate of 2% (Davies et al., 2008).

The estimated annual survival rate is believed to be 89%, although there have been no studies to prove as much. Survival rates between adults and juveniles are believed to similiar (Slooten et al. 2000). There is little to no movement between local populations (Pichler et al. 1998; Hamner et al. 2012).

Conservation Status

The IUCN red list first listed Hector's dolphin as vulnerable in 1990 (Reeves et al. 2013). In 2000, Hector's dolphin was relisted as endangered (Reeves et al. 2013), and currently remains endangered under the criteria of a projected decline of 50% is expected over 3 generations (Slooten et al. 2000). The current population of Hector's dolphins is estimated to be 7,270 individuals (Slooten et al. 2004). This is an estimated 73% decline from the estimated population size in 1970, a period spanning three generations (Slooten 2007). This trend is continuing today, as current management strategies are ineffective (Slooten et al. 2006a; Slooten 2007; Slooten et al. 2010).

Statement of Need

Legal and Regulatory

In 1970, the population of Hector's dolphins around the South Island was believed to be 29,316 individuals (Slooten 2007). However, the 70s marked a period of expanded fisheries. Gillnetting became more important and, as it grew, bycatch of Hector's dolphins increased. Between 1984 and 1988, 230 Hector's dolphins were reported to be killed by gillnet fisheries (Dawson 1991). Hector's dolphins are considered particularly vulnerable not only due to their restricted inshore ranges that coincide with prime fishing ground (Dawson 1991) but also because of the prey they eat. Small groups of dolphins (pods) were observed to be following fishing trawlers engaging in apparent foraging behaviors (Rayment & Webster 2009). It was assumed that the dolphins found foraging near the trawlers energetically advantageous, as prey was disturbed and more easily available. This association between dolphins and fishing vessels likely exacerbates the number of dolphins accidentally caught by fishing nets (Rayment & Webster 2009). In 60% of cases where the cause of death was able to be determined for Hector's dolphins, a fisheries-related cause was responsible (Department of Conservation & Ministry of Fisheries 2007a).

In 1988, New Zealand's Department of Conservation constructed its first Marine Mammal Sanctuary – the Banks Peninsula Marine Mammal Sanctuary (BPMMS; Figure 3). The Banks Peninsula Marine Mammal Sanctuary was designed to reduce the number of incidents of bycatch for an east coast population (Dawson & Slooten 2005). BPMMS covers 1,170 km^2, with a 4 nautical mile offshore boundary and convering 70km of coastline (Dawson & Slooten 2005; Slooten et al. 2006a). Commercial gillnetting is banned from October – March, when movement of prey brings Hector's dolphins closer to shore. Amateur gillnetting is banned within the BPMMS year-round (Slooten et al. 2006A; Department of Conservation & Ministry of Fisheries 2007a). Despite these protections, the populations protected by the BPMMS have experienced a similiar decline to their unprotected counterparts (Slooten et al. 2006a).

Figure 3: Map showing the current range of the Banks Peninsula Marine Mammal Sanctuary. (Source: New Zealand Department of Conservation)

Economic Impact

Gillnetting is an important part of the New Zealand economy. It's annual revenue exceeds $7 million, with most gillnetters averaging $60-70,000 in income per year. 80% of gillnetters earn 80%-100% of their income through fishing (Department of Conservation & Ministry of Fisheries 2007b).

Hector's dolphins, however, are valuable in their own right. In the Banks Peninsula Marine Mammal Sanctuary, swim with dolphin tours are operated by Black Cat Cruises. Black Cat Cruises offers tours 16 times a day November – March, 8 times per day in April and October, and 1 per day in May and September. Tours are not offered June – August. Each tour allows 12 guests per visit, and the cost is $145 per adult and $120 per child (Black Cat Tours 2014). Assuming that all tours are filled by adults each day they are offered, swim with dolphin tours have a potential annual revenue of $560,715. Additionally, dolphin watching tours are offered by seven commercial operations (Martinex et al. 2012). These operations have been operating for more than 25 years, and are currently allowed a combined maximum of 32 trips per day, including swim with dolphin tours (Martinez et al. 2012; Black Cat Tours 2014). However, unlike swim with dolphin tours are allowed to operate year-round without restriction (Martinex et al. 2012). Overall, ecotourism focused on Hector's dolphin bolsters the local economy and provides jobs for many locals. Tourists participating in the tours will likely further support the local economy by purchasing lodging, food, souveneirs, and general travel expenses while visiting for their tours.The marine mammal tourism industry has grown 3.7% per yer on average globally, and New Zealand seems to follow that trend (Martinez et al. 2012).

Although there is an undeniable economic benefit to dolphin-related tourism, the effects it has on the dolphins themselves may not be beneficial. Stones have been utilized since 2003 to encourage swimmer interactions with Hector's dolphins (Martinez et al. 2012). The stones, when hit together or against the surface of the water, seem to produce a noise that encourages dolphins to approach swimmers. Swimmers who use the stones experience more frequent and longer interactions with the dolphins (Martinez et al. 2012). These interactions may have an effect on short-term survival of the individuals participating in them, as the dolphins are not spending the time foraging or otherwise participating in behaviors that could increase survival (Bejder et al. 1999; Martinez et al. 2012). Martinez et al. (2012) also reported high levels of tail-slapping, a behavior that may indicate aggression (Slooten 1994) around swimmers, which may have further implications for swimmer effects on Hector's dolphins. Stone and Yoshinaga (2000) stated that habituation to both humans and boats was leading to an increased risk of mortality among Hector's dolpins, especially calves.

Socio-Cultural Impact

Hector's dolphins are important in the culture of the people indigenous to New Zealand, the Maori. Maori legend states that their ancestors first traveled to the islands of New Zealand on the back of a giant Hector's dolphin, Panereira (Taylor & Curry 2005). Due to this, Hector's dolphins are sacred to the Maori people. They also have a high spiritual value – many Maori today believe that when a person dies, they may be reincarnated. Some of those reincarnated souls are born into Hector's dolphins (Taylor & Curry 2005). Many Maori have advocated for the protection of Hector's dolphins, stating that it is both the ethical and cultural responsibility of the government of New Zealand to protect the only cetacean endemic to their waters (Taylor & Curry 2005).

Statement of Need

Despite their popularity in both tourism and local culture, the greatest threat to Hector's dolphins comes from anthropogenic sources. Gillnetting mortality results in up to 60% of fatalities for adults, despite regulations currently in place (Department of Conservation & Ministry of Fisheries 2007a).

Hector's dolphins have and estimated home range size of 49.69km, with a maximum alongshore range length of 107.38km observed for one individual (Bräger et al. 2002; Rayment et al. 2009). Although most sightings of Hector's dolphins have historically been recorded within 5 nautical miles of shore, recent research suggests several variables may be responsible for actual distribution across their range. Slooten et al. (2006) found that water depth was a more true indicator of dolphin densities than distance from shore. On the east coast, in and around the BPMMS, water remains relatively shallow (>20m in depth) for more than 15 nautical miles off shore (Slooten et al. 2006a) whereas the shelf on the west coast seems to only extend for 5 nautical miles off shore (Dawson et al. 2004). Seasonality also appears to have a role, as dolphins are more likely to follow prey closer to shore in the summer (Rayment et al. 2010).

The Banks Peninsula Marine Mammal Sanctuary extends 70km alongshore, with a 4 nautical mile offshore boundary (Dawson & Slooten 2005; Slooten et al. 2006a). These boundaries, as indicated above, may not even cover the full range of one Hector's dolphin. Dolphins move outside of these borders and are caught in gillnets concenctrated on and around the border of the sanctuary (Slooten et al. 2010). In addition, the dolphins that are unprotected greatly outnumber those that are protected by the sanctuary, and a more inclusive protection is necessary for the survival of the species.

Goal

To increase the population of Hector's dolphins, *Cephalorhynchus hectori hectori*, around the South Island to a sustainable level.

Objective 1:

Increase protection of dolphins inside the Banks Peninsula Marine Mammal Sanctuary to reduce the number of gillnet mortalities to 2.8 dolphin per year.

Action 1*:* Increase the offshore boundary of the Banks Peninsula Marine Mammal Sanctuary to 15 nautical miles.

Banks Peninsula Marine Mammal Sanctuary (BPMMS) was established in 1988 with a primary purpose of Hector's dolphin conservation (Dawson and Slooten, 2005). It is currently the only Marine Mammal Sanctuary that protects *C. hectori hectori*, but it the effectiveness of the Sanctuary has been questioned. Due largely in part to seasonal movements in which Hector's dolphins are found closer to shore in summer and further offshore in winter (Rayment et al. 2010), large proportions of the population may not be protected during the winter (Rayment et al. 2011). In summer, Slooten et al. (2006) reported that 78.6% of sightings were within the 4 nautical mile offshore boundary of BPMMS, whereas only 35.1% of sightings in winter were within the boundary. Density of dolphins remained high throughout the 15 nautical mile study area in winter, indicating that the offshore boundary should be at least extended to 15 nautical miles to effectively protect the population year-round (Slooten et al. 2006a).

Increased offshore boundaries will likely decrease gillnet mortalities for the populations protected by the BPMMS. This will allow the population to be sustainable.

Action 2: Increase the north and south alongshore boundaries of the Banks Peninsula Marine Mammal Sanctuary by 60 miles each.

It has been noted that while gillnet restrictions within the Sanctuary protect the dolphins therein, bycatch in adjacent areas may still be contributing to local population decline (Slooten et al. 2010). To reduce the level of mortality due to bycatch for the populations within BPMMS to a sustainable level, the north and south boundaries of the Sanctuary need to be extended (Rayment et al. 2009; Slooten et al. 2006a). To effectively protect the dolphins that are currently in waters adjacent to the sanctuary boundaries and manage a level of sustainable bycatch, it is suggested that the alongshore boundaries of

BPMMS are increased by 60 nautical miles while keeping the previously mentioned 15 nautical mile offshore boundary intact (Slooten et al. 2006a) (Figure 4). This estimate was reached without including the current population protected by the BPMMS in bycatch estimates.

Increasing the alongshore boundaries of the BPMMS will alleviate bycatch displacement on adjacent Hector's dolphin populations and on individuals whose home ranges expand beyond the current borders. The resulting reduction of gillnet mortalities will lead to a more sustainable population, however, it is difficult to estimate the effectiveness of such a plan without including the BPMMS population.

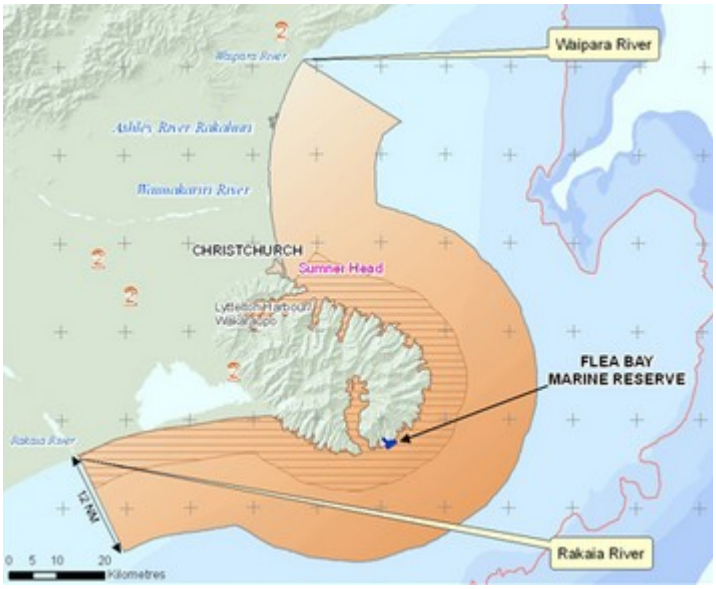

Figure 4: Map of proposed changes to the Banks Peninsula Marine Mammal Sanctuary with the current sanctuary boundaries represented by dashed lines and the proposed boundaries represented by orange shading. (Source: New Zealand Department of Conservation)

Action 3: Increase the north and south alongshore boundaries of the Banks Peninsula Marine Mammal Sanctuary by 30 miles each.

The home range of Hector's dolphins was estimated using kernel methods to be 49.69km (Rayment et al. 2009). It has been suggested that the daily movement and dispersal of dolphins within the BPMMS may result in individuals considered to be protected under the Sanctuary traveling outside its borders and thus risking legal gillnet entanglement (Slooten et al. 2000). To account for both individuals who primarily have home ranges outside of the sanctuary and who have a core range within the sanctuary but regularly travel outside of it, Slooten et al. (2006) suggest that extending the north and south alongshore boundaries by 30 nautical miles will result in a sustainable level of bycatch.

Again, this would include the aforementioned 15 nautical mile offshore boundary.

By including the current BPMMS population, it can be assumed that this area will be effective at reducing gillnet mortalities in the new protected area. The increased survival rates may prevent local population extinction.

Action 4: Enforce gillnet bans and restrictions within the Banks Peninsula Marine Mammal Sanctuary so as to reduce incidental bycatch.

It has been noted that, while commercial gillnetting is restricted to the winter months and amateur gillnetting is banned within the BPMSS, both operations have been seen within and on the sanctuary boundaries (Slooten et al. 2006a) and Hector's dolphin mortalities have been recorded as a result of these operations (Department of Conservation & Ministry of Fisheries 2007a). The exact number of illegal bycatch, however, is unknown. A prelimnary survey (Appendix A) should be sent to gillnet operations and made available to the public to gather information. This survey should be anonymous to encourage honesty, but should be treated as a low estimate of actual bycatch rates.

There is currently no set patrol of the BPMMS to persecute those in violation of gillnetting regulations. If a gillnet operation is found to be operating illegally in the BPMMS, the vessel should be fined up to $100,000. If illegal operation results in the death of a Hector's dolphin, the vessel shall be fined up to an additional $200,000 per individual and face a possible sentence in prison (Barlow et al. 1995).

A minimum of 30% of fines collected from illegal gillnetting will be returned to the continuation of gillnet enforcement within the BPMMS. This system will persecute illegal gillnet operators and will allow for the perpetuation of continued enforcement.

Decreasing the amount of gillnet mortalities within the BPMMS will increase the survival rate of protected Hector's dolphins and would likely lead to a sustainable population.

Action 5: No action.

The Banks Peninsula Marine Mammal Sanctuary is currently believed to be inefficient due to its size (Dawson and Slooten 2005; Rayment et al. 2010; Slooten 2007; Slooten et al. 2006a; Slooten et al. 2000). Continued use of gillnetting within and immediately surrounding the BPMMS is still affecting Hector's dolphin populations that are considered to be protected (Slooten et al. 2006a).

There has been no evidence of a recovering population within the BPMMS borders – the rate of

decrease of the BPMMS population is not statistically different from the rest of the population, as it should be if the population is truly protected and the BPMMS effective. If no changes are implemented and the current state of the BPMMS is upheld, local extinction is inevitable.

Assessment Protocol

To determine the effectiveness of actions taken to increase protection around the Banks Peninsula Marine Mammal Sanctuary (BPMMS), the total number of gillnet mortalities would need to be recorded in the years following implementation of protective legislature. To consider the actions taken to be successful, gillnet mortalities across the BPMMS must be reduced to 2.8 Hector's dolphins per year (Slooten et al. 2006a; Barlow et al. 1995). If such levels of bycatch were achieved, no further action beyond the continued enforcement of regulations would be needed. Although current gillnet mortality rates within the BPMMS remain unknown, a reduction of 75% or greater would likely result in population growth (Appendix B) and thus be considered a success. A successful plan implementation would require no action beyond continued regulation enforcement.

If gillnet mortalities are responsible for less than 60% of dolphin deaths (Department of Conservation & Ministry of Fisheries 2007a) but have not been reduced to 25% of their current level, the plan would be considered a low success. These levels, while undoubtedly an improvement over the current state, would not be sustainable and further action in the form of increased legislation would be needed. The source of mortality would need to be determined – ineffective alongshore or offshore boundaries (Slooten et al. 2006a) or continued bycatch within the sanctuary boundaries (Slooten et al. 2006a; Department of Conservation & Ministry of Fisheries 2007a) should be first investigated. Once the ultimate cause of continued gillnet mortalities is determined, legislation should be updated to reduce it to sustainable levels.

If there is no change in gillnet mortalities, or if gillnet mortalities increase, the objective will not be achieved and the action will be considered unsuccessful. At that point, further research regarding the ultimate cause of continued gillnet mortalities must be conducted and integrated into a revised management plan. Necropsies on dead dolphins may be used to discover the ultimate cause of death, and surveys should be distributed to gillnetting operations to determine whether there is a trend in the reasons dolphins are captured (Appendix A). Based on the results of the research, new legislation will need to be drafted and implemented to protect the dolphins where the previous legislation did not.

Objective 2:

Increase protected habitat across the South Island, focusing on areas with high density populations.

Action 1: Construct additional Marine Mammal Sanctuaries on the South Island using the current criteria for Banks Peninsula Marine Mammal Sanctuary.

Areas of high-density populations of Hector's dolphins are currently unprotected, or are protected by ineffective measures. For example, the west coast population (considered Cape Farewell to Awarua Point) only has a restriction on gillnetting to 2 nautical miles offshore (Slooten & Dawson 2010). However, this area encompasses much of the population of Hector's dolphins - an estimated 5,388 individuals out of the believed 7,270 population (Slooten et al. 2004). Collectively, the abundance of Hector's dolphins on the north, east (including the BPMMS), and south coast is reported to be 1,880 individuals (Dawson et al. 2004).

To restore the population of Hector's dolphins to sustainable levels, additional Marine Mammal Sanctuaries should be constructed. On the west coast, the area of highest abundance appears to be around Westport and Hokitika (Slooten et al. 2004) and Marine Mammal Sanctuaries should be constructed in these areas. Waewae Bay on the south coast and Timaru on the east coast are additional areas that may have high densities of Hector's dolphins (Dawson et al. 2004) and should be investigated for Marine Mammal Sanctuary potential (Figure 5).

As described above, in Objective 1, Action 2, the criteria currently used in BPMMS is believed ineffective due to a shift in bycatch from the sanctuary to adjacent areas and a small area design (Slooten et al. 2006a). If additional Marine Mammal Sanctuaries are constructed using the same criteria, population decline of Hector's dolphins may decrease to a slower rate, but will not recover to sustainable levels.

Figure 5: Proposed locations of new Marine Mammal Sanctuaries are highlighted in green at: A) Westport, B) Hokitika, C) Waewae Bay, and D) Timaru. Orange represents current range of Hector's dolphins.

Action 2: Construct additional Marine Mammal Sanctuaries on the north and west coast of the South Island using more inclusive criteria.

The high-density areas considered in Objective 2, Action 1 should be considered here for protection as well. These areas include Westport and Hokitika on the west coast (Slooten et al. 2004), Waewae Bay on the south coast, and Timaru on the east coast (Dawson et al. 2004). However, the construction of these Marine Mammal Sanctuaries would *not* follow the current criteria for BPMMS. Instead, they would follow the criteria suitable for each individual population, taking the distribution and movement of individuals into account, as well as the possibility of shifting bycatch to adjacent populations and the effect it would have on them. The U.S. Marine Fisheries Service model (Barlow et al. 1995) will be used to determine sustainable levels of bycatch in each protected area, and effective bans on gillnetting will be put into place, again taking the distribution and dispersal of each population into consideration.

If additional Marine Mammal Sanctuaries are constructed with stricter policies regarding appropriate boundaries and gillnet bans, the population of Hector's dolphins should increase due to a resultant decrease in mortality.

Action 3: No action.

If no action is taken, the area of protected habitat is currently too small to sustain population levels (Slooten 2007). The population will continue to decline until it reaches extinction.

Assessment Protocol

If 4 new Marine Mammal Sanctuaries are constructed in Westport and Hokitika (west) (Slooten et al. 2004), Waewae Bay (south), and Timaru (east) (Dawson et al. 2004) with boundaries and regulations appropriate for each individual area, this plan will be considered extremely successful. Bycatch in these areas should be sustainable as determined by the marine mammal stock assessment model employed by the United States National Marine Fisheries Service (Barlow et al. 1995). If all areas are constructed with individual regulations and sustainable bycatch, no further action beyond continued enforcement of regulations will be necessary.

If 2 or 3 new Marine Mammal Sanctuaries are constructed, including Westport and Hokitika (Slooten et al. 2004) with custom boundaries and regulations that result in sustainable levels of bycatch (Barlow et al. 1995) this plan will be considered successful. To further increase the effectiveness of this plan, further action should be taken to construct 1 or 2 additional Marine Mammal Sanctuaries using

similar custom regulations for sustainable bycatch, for a total of four Marine Mammal Sanctuaries other than the existing Banks Peninsula Marine Mammal Sanctuary.

If all 4 Marine Mammal Sanctuaries are constructed with individually developed boundaries and regulations that result in decreased levels of bycatch that are not sustainable, this plan will be considered fairly successful. To increase effectiveness, the ultimate source of continued gillnet mortalities should be investigate, and adaptive legislation implemented to counteract that.

The construction of any number of Marine Mammal Sanctuaries with a decreased number of gillnet mortalities will be considered a low success. Sustainable levels of bycatch should be determined using the US National Marine Fisheries Service model (Barlow et al. 1995). Mortalities should be investigated to find the ultimate cause and new regulations should be formed based on the results. These regulations should be implemented and evaluated at a later date to determine effectiveness.

The construction of any or no additional Marine Mammal Sanctuaries with continued or increased levels of gillnet bycatch will result in an assessment of unsuccessful. The most likely obstacle to the construction of Marine Mammal Sanctuaries will come in the form of protest from commercial and amateur gillnetters. However, current levels of bycatch are unsustainable and will result in both local and species extinction, as current protected area for Hector's dolphins is too small to be effective (Slooten 2007). Surveys should be conducted (Appendix A) to determine the areas and operations where gillnet mortalities are highest, and those should be addressed first. The construction of Marine Mammal Sanctuaries with effective legislature regarding boundaries and gillnet regulations should be constructed, with every attempt to balance the needs of Hector's dolphins with the concerns of gillnetters. However, without the cosntruction of the Marine Mammal Sanctuaries, Hector's dolphins will continue their decline until they reach extinction.

Objective 3:

Reduce fishery bycatch mortalities across the nonprotected South Island populations by 75%.

Action 1*:* Determine a sustainable level of bycatch for each management area.

A preliminary deterministic population model indicates that the South Island population of Hector's dolphins can not sustain itself until fisheries related bycatch reaches 25% of its current level (Appendix B). The United States National Marine Fisheries service has developed a model to determine the sustainable amount of bycatch for marine species (Barlow et al. 2005). This model has

been succesfully used to determine the sustainable amount of bycatch for New Zealand sea lions, and should be applicable to Hector's dolphins as well (Slooten et al. 2006a). The model requires 95% or greater probability that populations starting at the maximum net productivity level (MNPL) stay at or above that level after 20 years and that populations starting at 30% of carrying capacity (K) recover to at least MNPL after 100 years (Barlow et al. 2005). This model was used to determine the sustainable level of bycatch for hector's dolphins in and around the BPMMS, with 2.8 dolphins per year being acceptable if the sanctuary population was included and 1.6 dolphins per year being acceptable if it was not (Slooten et al. 2006a).

By determining an acceptable level of bycatch for populations in all management areas around the South Island, comprehensive bycatch management plans can be developed and implented.

Action 2: Develop and enact gillnet restrictions in each South Island management area.

Using the sustainable bycatch estimates obtained in Objective 3, Action 1, comprehensive restrictions can be enacted. Using the most recently obtained population demographics for each management area (Dawon et al. 2004; Rayment et al. 2011; Rayment et al. 2010; Slooten et al. 2004; Slooten et al. 2006a) effective restrictions can be set. For areas with outdated or missing demographic data, line-transect boat an aerial surveys should be conducted to determine the distribution of Hector's dolphins in the affected area (Dawson et al. 2004; Rayment et al. 2010; Slooten et al. 2006a). Once distribution data is obtained, each management area can devise a management plan that will keep bycatch within the aforementioned constraints.

Current levels of bycatch are currently unknown throughout most of the range of Hector's dolphins. Surveys should be conducted to determine a low estimate of the amount of bycatch currently occurring (Appendix A). By detemining the current levels of bycatch, we can better manage for reducing them to sustainable levels.

Any changes to regulation will be publically anounced and known operations that will be affected will recieve mailed notices of regulation changes. Additionally, any continued bycatch of dolphins should be reported to create adaptative management plans. If a reporting vessel is found to be following all regulations and restrictions at the time of bycatch, no penalization will occur.

If adaptive gillnet restrictions can be enacted in each management area, Hector's dolphin populations should recover to a point where they are sustainable. The Department of Conservation and the Ministry of Fisheries (2007a) report that fisheries bycatch accounts for 63% of known Hector's

dolphin mortalities. Eliminate of this single mitigating factor may be key to species recovery.

Action 3: No action.

If no action is taken, Hector's dolphins will continue to decrease. Local populations will reach extinction and, within 3 generations are expected to decline 74% (Slooten 2007).

Assessment Protocol

To consider this plan extremely successful, gillnet mortalities across the South Island populations of Hector's dolphins must be reduced by 75% (Appendix B). This will allow population growth and for Hector's dolphins to recover. No further action will be needed except for the continued enforcement of regulations.

If gillnet mortalities are reduced by 50%, this plan will be considered fairly successful. The population will still be decreasing ($r = -0.0153$), but at much lower rates than are currently experienced ($r = -0.0526$) (Appendix B). Gillnetting restrictions should be re-evaluated for effectiveness in each management area and adjusted to support sustainable bycatch as needed.

If gillnet mortalities are reduced by 25%, this plan will be considered a low success. The population will still be decreasing at unsustainable levels ($r = -0.0356$) but will be lower than ar currently experienced (Appendix B). Gillnetting restrictions should be re-evaluated for effectiveness in each management area and adjusted to support sustainable bycatch. Stricter regulations may be needed, and additional research may be necessary to support these restrictions. More detailed research on the life history of Hector's dolphins could be particularly useful, and life history and survivability studies should be considered first if the plan is not succeesful (Appendix C).

If gillnet mortalities stay at the same rate or increase, this plan will not be considered successful. Current levels of bycatch, accounting for ~63% of all known causes of death (Department of Conservation & Ministry of Fisheries 2007a) are unsustainable and will result in a 75% decrease in population size over the next 39 years (Slooten 2007). Levels of sustainable bycatch should be re-evaluated using the most recent research and the U.S. Marine Fisheries Service model (Barlow et al. 1995) and gillnetting restrictions should be completely revised. Further research should be conducted to determine main causes of inaccuracy in calculations and of bycatch mortality to fully understand what regulations need to be enacted.

Conclusion

The ultimate cause of decline in Hector's dolphins is caused by humans. Incidental bycatch in gillnets is avoidable and if proper protective legislation is created Hector's dolphin could be saved from extinction. The most effective method of achieving these goals will be to increase the protective legislature around Banks Peninsula Marine Mammal Sanctuary to include wider boundaries and less incidental bycatch, to produce 4 new Marine Mammal Sanctuaries around high-density populations of Hector's dolphins and to ensure that the protection in each Sanctuary is appropriate, and to increase the protection for all dolphins outside of the Marine Mammal Sanctuaries. This species is found only in New Zealand waters, and thus it is solely up to the New Zealand government to prevent the extinction of Hector's dolphins.

Appendix A: Gillnet Operations Survey

NOTE: THIS IS AN EXAMPLE SURVEY FOR THE BANKS PENINSULA MARINE MAMMAL SANCTUARY. LOCATIONS WOULD NEED TO BE EDITED FOR SURVEYS FOR OTHER SANCTUARIES.

Hector's dolphins are an endangered species of dolphin found only in New Zealand waters. The greatest known threat to Hector's dolphins is gillnet (otherwise known as set netting) entanglement. In order to find a balance between local fisheries operations, we would like to invite you to fill out this anonymous survey about gillnetting in the Banks Peninsula Marine Mammal Sanctuary. Please check all answers that apply.

Q1: Have you ever, participated in a gillnetting operation that operates between Summer Head and Rakaia River?

__ Yes, I am currently participating in gillnetting operation(s)

- Is the operation: Commercial __ Amateur __
- What year did you begin working for the operation? _____

__ Yes, I have previously participated in gillnetting operation(s)

- Was the operation: Commercial __ Amateur __
- Between what dates did you work for the operation(s)? _____

__ No, I have never participated in gillnetting operations

Q2: If you answered **yes** to question 1: From 1988 to present, have you participated in gillnetting within the boundaries of the Banks Peninsula Marine Mammal Sanctuary?

__ Yes

- Was the operation: Commercial __ Amateur __

__ No

- Was the operation: Commercial __ Amateur __

___ I answered no to Question 1

Q3: If you answered **yes** to question 2: To the best of your knowledge, did your gillnetting operation follow the current restrictions and/or bans in place within the Banks Peninsula Marine Mammal Sanctuary?

(Note that this survey is anonymous and no legal action will be taken based on your answers)

__ Yes, my operation operated within the regulations

- Was the operation: Commercial __ Amateur __

__ No, my operation did no operate within the regulations

- Was the operation: Commercial __ Amateur __

__ I do not know if my operation was following regulation

- Was the operation: Commercial __ Amateur __

__ I answered no to Question 2

Q4: If you answered **yes** to question 2: Has your operation ever had bycatch of a Hector's dolphin, to the best of your knowledge?

__ Yes

__ No

__ I do not know

__ I answered no to Question 2

Q5: If you answered **yes** to question 3:

- Was the operation: Commercial __ Amateur __
- How many dolphin(s) do you know of being accidentally caught? _____
- Did the bycatch result in the death of the dolphin? Yes __ No__ I don't know __

For multiple occurences with different outcomes, please explain:

_____

_____

_____

- What year and month did each incident occur? _____
- Was the incident(s) reported to the DoC or MoF? __ Yes __ No __ I don't know

Q6: **Regardless of your answers to previous questions**: Have you ever known someone else to have captured a Hector's dolphin while gillnetting between Summer Head and Rakaia River?

__ No

__ Yes

- If **yes**, please provide as much information about the incident as possible:

_____

_____

_____

Thank you for your time! If you have any other comments, please add them below or email us at EMAILHERE@EMAIL.COM. We appreciate you dedication to helping us find a balance between gillnetting operations and Hector's dolphin!

Additional Comments:

_____

_____

_____

_____

Survey Use

Current levels of fisheries-related bycatch are unknown throughout most of the range of Hector's dolphins (Slooten et al. 2006a). Mortalities where fisheries bycatch is the cause account for 63% of all known causes of death in Hector's dolphins (Department of Conservation & Ministry of Fisheries 2007a). However, this number is likely to vary from population to population, depending on the fisheries industry of each region, regulations and restrictions in place, and the distribution and abundance of the local dolphin population. As such, it is important to determine the actual rate of byctach for each population.

These surveys can be distributed in areas of interest to establish a low estimate of bycatch rates. No legal action should be taken against those taking the survey, to encourage truthful answers. Still, it may be assumed that not every answer will be truthful – the knowledge that they are admitting to illegal activity, anonymous or not, may discourage truthful answers or survey responses in general.

Appendix B: Population Model and Matrix

Population models are a useful tool in determining the life history stages of a species. They can be manipulated to determine the effects of changes in survivability. Here, a deterministic model was used to calculate the probability of survival for Hector's dolphins using life history data provided by several sources (Slooten & Lad 1991; Slooten 1991; Webster et al. 2009; Slooten et al. 2000). A matrix is constructed based on these life history stages (Table 1). As females are the limiting factor for reproduction in Hector's dolphins, this model used female demographic information.

Age	Stage	Survival	Fecundity
0	Juvenile	0.84	0
1-7	Immature Individual	0.89	0
8-23	Mature Individual	0.89	0.0927

Table 1: Life history table for Hector's dolphins. Fecundity was calculated by multiplying the number of offspring a female could have (1) by the probability of reproduction (0.2083)by the probability of female survival (0.89) by the ratio of female offspring (0.5)

For Hector's dolphins, life history can be divided into three stages: Juvenile, Immature Individual, and Mature Individual. Juveniles are dolphins that are still nursing, typically until 1 year of age. During this time period, the likelihood of survival is estimated to be 84% (Slooten et al. 2000). Immature adults are no longer nursing and dependant on their mothers, but are not sexually mature. At 7 years of age, the dolphin reaches sexual maturity and can produce one offspring every 2-3 years (Slooten 1991; Slooten et al. 2000). In the model, dolphins were assumed to live to the maximum life expectancy of 22 years (Slooten & Lad 1991; Webster et al. 2009). There is no known difference in survival between immature and mature individuals , so both had survival rates of 0.89 (Slooten et al. 2010). By inputting this information into a matrix, a population model was created (Figure 6).

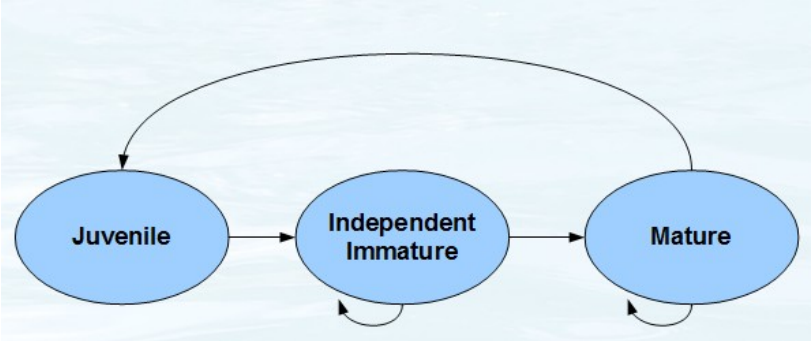

Figure 6: Population model for Hector's dolphins, including the three life stages. Arrows represent the potential of an individual from one life stage to become or produce an individual from another life stage.

The Department of Conservation & Ministry of Fisheries (2007) has concluded that 60% of

Hector's dolphins mortalities are caused by gillnets. By manipulating this factor, the model was used to determine the population trends of Hector's dolphin at 0% (Figure 7), 25% (Figure 8), 50% (Figure 9, 75% (Figure 10) reduction of current gillnet mortalities. I assumed that there was no difference in gillnet mortality rates between adults and juveniles. Using these predictions, I was able to determine that 75% reduction of gillnet mortalities would be necessary for an increasing population trend. The reduction of 75% of gillnet mortality rates increased the survivability of Hector's dolphin juveniles to 0.912 and the survivability of adults to 0.9395 (Table 2). All models were run using only the female demographic – for example: assuming an equal sex ratio, the starting population of 7,270 individuals was reduced to 3,635 *female* individuals.

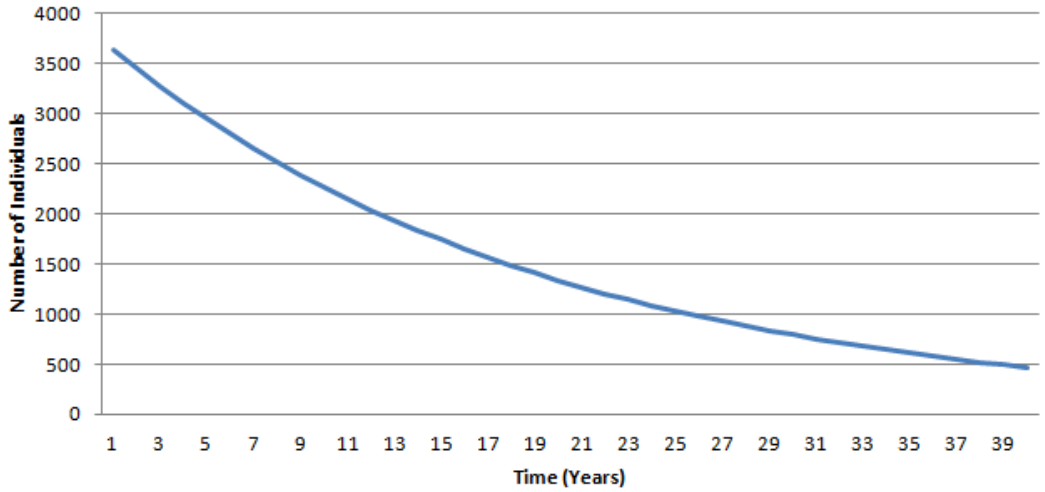

Figure 7: Population trend of Hector's dolphin if gillnet mortalities are reduced by 0% (r = -0.05258). At the end of the 39-year period, the population will be 468 individuals (88% decrease).

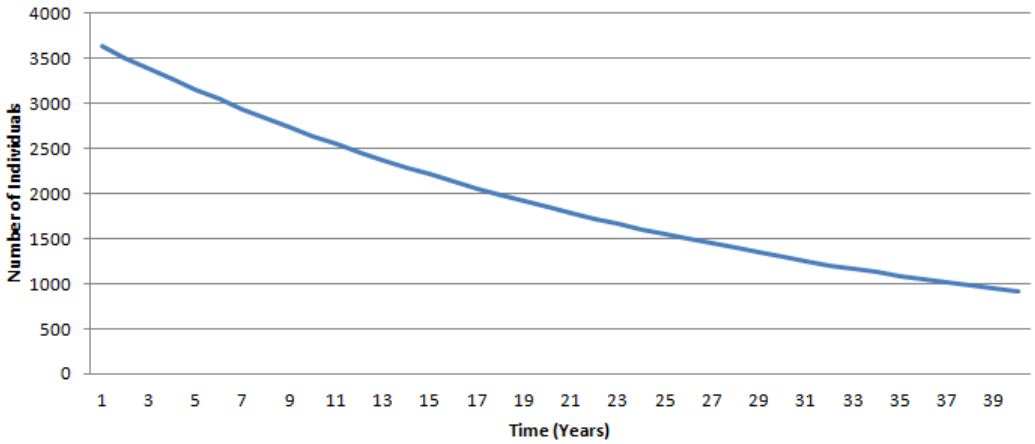

Figure 8: Population trend of Hector's dolphin if gillnet mortalities are reduced by 25% (r = -0.03557). At the end of the 39-year period, the population will be 908 individuals (75.02% decrease).

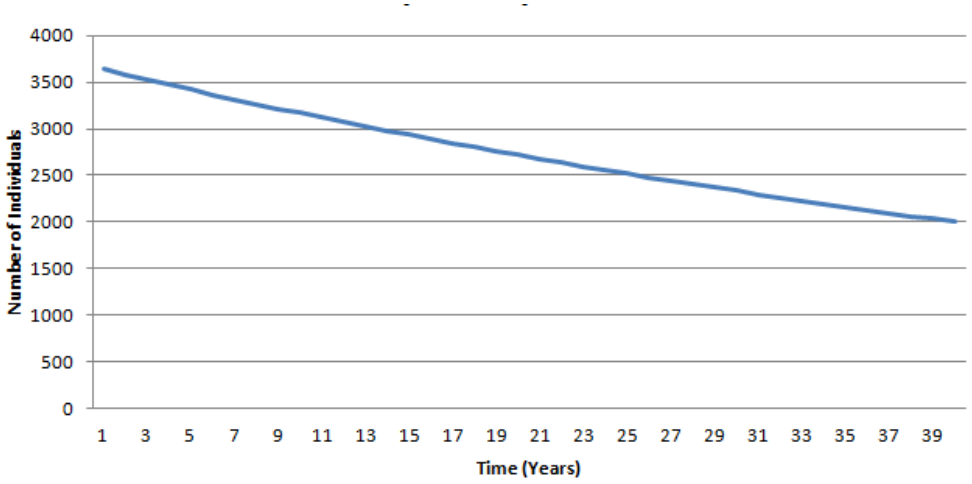

Figure 9: Population trend of Hector's dolphin if gillnet mortalities are reduced by 50% (r = -0.01529). At the end of the 39-year period, the population will be 2003 individuals (44.91% decrease).

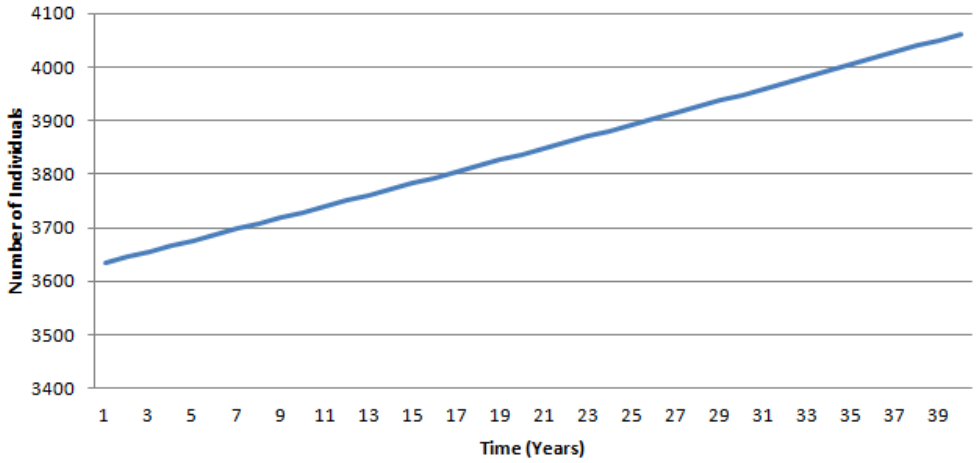

Figure 10: Population trend of Hector's dolphin if gillnet mortalities are reduced by 75% (r = 0.00284). At the end of the 39-year period, the population will be 4062 individuals (12% increase).

Gillnet Mortality Reduction	Life Stage	Survivability	Change in Survivability
0%	Juvenile	0.84	0
	Adult	0.84	0
25%	Juvenile	0.865	+0.025
	Adult	0.9065	+0.0165
50%	Juvenile	0.888	+0.048
	Adult	0.923	+0.033
75%	Juvenile	0.912	+0.072
	Adult	0.9395	+0.0495

Table 2: The effect on reducing gillnet mortalities on survivability of Hector's dolphins. As there is no difference between Immature Individual and Mature Individual survival, the two life stages were compressed into Adult.

Appendix C: Hector's Dolphin Life History Study Design Proposal

Hector's dolphins, *Cephalorhynchus hectori hectori,* are the only species of dolphin found only in New Zealand waters. This species is valuable not only because of it is found nowhere else in the world, but due the cultural significance to the Maori people and economic value. However, these dolphins are being killed by human activity, and are in danger of extinction.

Hector's dolphins are one of the smallest dolphins in the world, with a maximum length of 1.6m, and they are also one of the rarest. The South Island populations are as low as 7,270 individuals and due to the low rate at which they reproduce, they cannot replace the amount of dolphins being killed by gillnetting annually. Because they are found nowhere else in the world, the protection of Hector's dolphins is the sole responsibility of New Zealand.

Cultural Value

The Maori people have a culture steeped in the importance of Hector's dolphins. It is said that their earliest ancestors were brought to the island on the back of a great Hector's dolphin, Panereira, and it is still believed today that when someone dies, their soul is returned to the sea. Some people are then reincarnated as dolphins.

Economic Value

With a potential annual $565,000 profit from dolphin tours in the existing Marine Mammal Sanctuary in Akaroa Harbor, Hector's dolphins are a source of income for many. In addition to the price for the tours themselves, tourists are likely to pay for food, lodging, and travel costs. The construction of additional Marine Protection Areas could provide an economic benefit to local communities.

Despite their economic and cultural value, Hector's dolphins are declining rapidly. The most prominent cause of decline is gillnet mortalities, which account for up to 63% of all deaths. To truly understand the effects of gillnetting and how to best save this species from extinction, their life history must be known – particularly survival rates. There have been no empirical studies done on the subject, but to truly understand and prevent Hector's dolphin extinction, funding is necessary. Attached is the design for a study to determine these important life history characteristics, which we hope you'll consider funding.

Survival Rates in Juvenile Hector's Dolphins, Determined by Mark-Recapture

Justification

Hector's dolphins are at risk of extinction due to incidental bycatch mortalities. Management practices need to be enacted to preserve this species and allow them to recover. However, little is known about the life history of Hector's dolphins, and thus any attempts to manage them may be ineffective due to a lack of accurate information. In particular, little is known about the survival rates of juvenile Hector's dolphins into adulthood (Slooten et al., 2006a).

Research Objectives

The goal of this research is to determine the juvenile-adult survival rates of Hector's dolphins. The main objective will be to determine the rate of survival of Hector's dolphins until they are two years of age in five distinct populations: Banks Peninsula, Westport, Hokitika, Waewae Bay, and Timaru (Dawson et al. 2004, Slooten et al. 2004, Slooten et al. 2006a).

Methods

- Study will take place in five high-density locations: Banks Peninsula, Westport, Hokitika, Waewae Bay, and Timaru.
- Study will last a minimum duration of 5 years to limit yearly stochasticity.
- Inital mark dates will occur in June, with additional mark dates through August.
- Marking will occur the first four years of the study.
- Calves will be marked with individual combination of color tags, inscribed with a number to call if calf is found deceased, that will be affixed to the dorsal fin.
- Twice a month after the initial marking period, technicians will identify the dolphins from a motorized boat based on tag colors.
- Beach patrols will be conducted on a weekly basis to identify any deceased individuals along the coast of the study area.
- After data collection, data will be analyzed using Program MARK to assess juvenile survivability.
- Logrank tests may be used to determine any difference between juveniles inside and outside of protected areas, if both population types are represented in the study.
- If at any time, survivability of juveniles or adults is believed to be influenced by mark-recapture efforts, the study will be halted until measures are in place to eliminate effects on mortality.

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