Management of gillnet bycatch of cetaceans in New Zealand

STEPHEN M. DAWSON[+] AND ELISABETH SLOOTEN[*]

University of Otago, PO Box 56, Dunedin, New Zealand

Contact e-mail: steve.dawson@stonebow.otago.ac.nz

ABSTRACT

Bycatch of dolphins in inshore gillnets first attracted scientific and management attention in New Zealand in the 1980s. During 1984-88, 50-150 dusky dolphins were killed each year at Kaikoura in gillnets set at the surface to catch bait for rock lobster. At the same time, annual catches of 20-100 Hector's dolphins occurred in Canterbury waters in bottom-set commercial and recreational gillnets. These catches resulted in the banning of surface-set gillnetting at Kaikoura in 1989 and in the creation of the Banks Peninsula Marine Mammal Sanctuary in 1988 to protect Hector's dolphin. An additional gillnet closure was established to protect North Island Hector's dolphin in 2003. A key problem is that current information on catches in these and other areas is scant. One observer programme has been successfully implemented in a commercial gillnet fishery (Canterbury area, 1997/98 fishing season). Its estimate of Hector's dolphin bycatch (17) is clearly unsustainable by the local population. Pingers have been voluntarily used in these fisheries, but there are no data establishing their effectiveness, and it has not been possible to ensure consistency of pinger use. There are no reliable estimates of numbers taken in recreational fisheries. Area closures are used to mitigate gillnet bycatch of Hector's dolphin, however it appears that the Banks Peninsula Marine Mammal Sanctuary is not large enough to ensure the persistence of the Canterbury population. There is a bycatch limit in place for this population, although it is unenforced. We argue that management of this species via bycatch limits is not practical, however. Hector's dolphin's low abundance and separation into several distinct populations means that appropriate bycatch limits would be very small, and this necessitates very comprehensive observer coverage to be confident they are not exceeded. We propose that increasing the size of protected areas is the most reliable option for conservation.

KEYWORDS: CONSERVATION; FISHERIES; GILLNETS; INCIDENTAL CATCHES; REGULATIONS; SANCTUARIES; STATISTICS; SUSTAINABILITY; TRAWLS

INTRODUCTION

Incidental catch in gillnets is probably the most serious conservation issue facing small cetaceans (e.g. Bjørge *et al.*, 1994; Perrin *et al.*, 1994; Hall and Donovan, 2002). In some cases such bycatch endangers local populations (e.g. Martien *et al.*, 1999; Dawson *et al.*, 2001; Secchi and Wang, 2002) and species (Taylor and Rojas-Bracho, 1999). Few people outside the community of marine mammal scientists realise how effective gillnets are at catching small cetaceans. For example, in Peru a directed fishery has killed many thousands of dolphins annually for human consumption. No technique more effective has been found for this than gillnetting (Read *et al.*, 1988; Van Waerebeek *et al.*, 1999).

Three generic strategies are available to ensure that bycatch is sustainable. The most obvious strategy is to remove the relevant fishing gear (e.g. gillnets) from the area of interaction. Time/area closures, if properly designed and enforced, will eliminate bycatch in the closed area. Such measures are seldom popular with fishermen, however, and by displacing fishing effort from one area to another can act to move the entanglement problem rather than solve it (e.g. see Murray *et al.*, 2000). One beneficial side product of such a strategy is that gillnet-free areas established for marine mammals can have conservation benefits for other species, especially fish and seabirds (e.g. Darby and Dawson, 2000).

The second strategy involves modification of the fishing gear in order to reduce its likelihood of catching cetaceans. This may involve changes to the way the gear is rigged (e.g. Hembree and Harwood, 1987) or more recently the addition of acoustic pingers to nets to displace cetaceans from the area around the net, or warn them of its presence (e.g. Kraus *et al.*, 1997). Gear modification is appealing because fishing can continue, but requires detailed research to find effective measures, and long-term monitoring to ensure that gear modifications remain effective (Dawson *et al.*, 1998; IWC, 2000).

The third strategy involves setting a sustainable bycatch limit (e.g. 'Potential Biological Removal' or PBR; Wade, 1998). The fishery, if it exceeds that limit, is closed, or required to formulate a 'take reduction plan' to ensure that the limit is not exceeded in future. The PBR approach is used routinely by the National Marine Fisheries Service (NMFS) in the US. It is also used to manage trawl bycatch of New Zealand (NZ) sea lions (*Phocarctos hookeri*) in New Zealand, where its implementation has resulted in the early closure of the Auckland Islands trawl fishery for squid each year from 1996-2002[1], and has motivated the industry to explore ways of reducing bycatch. As in the gear modification strategy, high observer coverage is required to ensure that the number of incidental takes is known with reasonable precision.

The vast majority of gillnet vessels in New Zealand are small (96% were <15m in 1995, the most recent year for which data are published; Peacey, 1996). While gillnetting is used commercially to target a wide range of species, most gillnetting on open coasts is directed towards Chondrichthyan species, notably rig (*Mustelus lenticulatus*), school shark (*Galeorhinus galeus*) and elephant fish (*Callorhychus milii*). In 1995, these gillnet fisheries together contributed less than 1% of the primary value of all New

[1] The fishery was officially closed in each of the years. In several years the boats pulled out early, correctly anticipating closure (Childerhouse, pers. comm.).

[+] *Department of Marine Science.*
[*] *Zoology Department.*

Zealand fisheries combined (Peacey, 1996). These species are targeted mostly in summer, in waters less than 100m deep.

In most countries, gillnets are used only by a licensed commercial fishing industry. In New Zealand, any member of the public may use a gillnet (gillnets used by recreational fishers are required to be <60m long). No licence is required and there are few detailed data on recreational gillnetting practices, or on the amount and distribution of effort.

Given that New Zealand is seen in some quarters as an example to follow in terms of fisheries management (e.g. Batkin, 1996), it seems appropriate to evaluate its management of the bycatch of cetaceans in gillnets.

INCIDENTAL CAPTURE OF CETACEANS IN NEW ZEALAND

Four small cetacean species are regularly seen off New Zealand coasts. They are Hector's dolphin (*Cephalorhynchus hectori*), dusky dolphin (*Lagenorhynchus obscurus*), common dolphin (*Delphinus delphis*) and bottlenose dolphin (*Tursiops truncatus*).

Common and bottlenose dolphins

The distribution of common and bottlenose dolphins has little overlap with intensive gillnetting, and therefore they may largely avoid gillnet entanglement. However, there are no observer programmes or other systematic attempts to estimate the level of bycatch for common and bottlenose dolphins.

Dusky dolphin

From specimens that were submitted for dissection, and from his discussions with fishermen, Cipriano (pers. comm.) estimated that 50-150 dusky dolphins were killed at Kaikoura each year between 1984-88. The highest mortality was from gillnets set at the surface to catch kahawai (*Arripis trutta*) to bait pots for rock lobster (*Jasus edwardsii*). Fishermen spoke of 'disaster sets' in which 20 or more dolphins were killed in one net.

Dusky dolphins are occasionally caught in commercial bottom-set gillnets set for tarakihi (*Nemadactylus macropterus*), rig (*Mustelus lenticulatus*), ling (*Genypterus blacodes*) and groper (*Polyprion oxygeneious*) at Kaikoura. This netting occurs inside and along the edge of the continental shelf, in waters 100-500m deep, typically within 500m to 18km of shore. Dusky dolphins feed mostly at night, beyond the shelf edge, on animals associated with the deep scattering layer. During the day they mainly rest and socialise inshore (Würsig *et al.*, 1997). Thus, during the day, when they are near the nets on the shelf edge they are probably not diving deep, and are hence not so vulnerable to nets set on the bottom. Local gillnetters believe that setting and hauling operations appear to pose the greatest risk (D. Burkhart, G. Melville, pers. comm.). With the removal of part-timers from the fishery when the Quota Management System was established in 1986 (Clark *et al.*, 1988), gillnetting practices appear to have improved, and reports of dusky dolphin catches have dropped substantially. However, in the absence of an observer programme or other systematic attempts to assess the level of bycatch, neither the magnitude of catches nor their impact on the population is known.

Hector's dolphin

Due to its close inshore distribution, Hector's dolphin has the greatest spatial overlap with gillnetting grounds and is known to be caught throughout its range (Dawson *et al.*, 2001). Despite this, serious attempts to quantify numbers caught have been made only in the Canterbury area. An interview programme established that commercial and recreational fishing killed some 20-100 per year in this area during 1984-1988 (Dawson, 1991). These catches, along with population viability analyses (Slooten and Lad, 1991) and studies of survival rate (Slooten *et al.*, 1992) contributed to the establishment of the Banks Peninsula Marine Mammal Sanctuary in 1988 (see Dawson and Slooten, 1993 for details).

Research since the creation of the sanctuary has confirmed its necessity. Pichler and Baker (2000) found a significant loss of genetic diversity in Canterbury from nine historical lineages, to five current. The timing of the loss matched closely with the introduction of mechanised gillnet fishing, and the resultant high dolphin bycatch (Dawson, 1991; Pichler and Baker, 2000). Additionally, Martien *et al.*'s (1999) modelling, based on gillnet effort and a catch rate determined from Dawson's (1991) interviews, indicate that the number of Hector's dolphins on the east coast of South Island has probably been in decline since the late 1970s when gillnetting became widespread. Using the most conservative estimates for maximum population growth, the model estimates that the population in 1984 was about half its size in 1970.

An observer programme (Starr and Langley, 2000) in 1997/98 off the Canterbury coast observed 6 mortalities in 214 gillnet sets, and 1 mortality in 434 trawl shots (Baird and Bradford, 2000). When stratified by area and season, observed gillnet bycatches extrapolate to an estimated total of 17 (ignoring setnet effort for spiny dogfish; Starr, 2000). Since commercial gillnetting is now illegal within the sanctuary, these catches are distributed to the north, south and offshore of it. Recent line-transect surveys indicate a total population of 1,198 in this region (Motunau to Timaru, CV= 27%; Dawson *et al.*, 2004). It can be argued that since the role of the sanctuary is to protect the dolphins within it, those animals should be omitted from any calculation of what might be an allowable bycatch. However, even if included, the US PBR model only yields an 'allowable' bycatch for this area of about two dolphins per year[2]. The estimated mortality in 1997/98 is more than eight times this figure. Due to paucity of data and low observer coverage, Baird and Bradford (2000) did not attempt to estimate numbers taken in trawls. The total trawling effort in Canterbury inshore waters was about 14,900 shots in 1997/98 (data from Catch Effort Landing Returns data only, areas 20 and 22; Baird and Bradford, 2000). It is clear that even low capture rates could result in a significant number of captures. Trawling is permitted within the sanctuary.

Frequent catches of Hector's dolphins occur in gillnets set off the west coast of South Island. The commercial gillnetting fleet here is small, but is supplemented by significant amateur fishing on certain parts of the coast. For example, off Ngakawau (25km north of Westport) local fishermen set nets attached to stakes permanently driven into the sand. The catch is cleared at low tide, and in some cases traded. It is illegal to set nets from stakes, or in such a way that fish can be stranded by the falling tide, and non-

[2] Using the NMFS system, for a dolphin listed as endangered, results in an allowable bycatch of 0.2% of the lower 60% confidence interval of abundance.

commercial fishermen are prohibited from trading their catch. Ministry of Fisheries officials have met with fishermen to clarify these points, but there has been very little action to ensure compliance, despite this longstanding problem. Hector's dolphin densities in this area are high (Slooten *et al.*, 2004) and several net-marked dolphins are found beachcast each year (Neale, pers. comm.). There are no formal estimates of bycatch for this fishery, or any other west coast gillnet fishery.

The population of Hector's dolphin found off the west coast of North Island (Dawson *et al.*, 2001) is the most at risk of extinction. This population, now recognised as a separate subspecies (and renamed Maui's dolphin; Baker *et al.*, 2002) is very small (population estimate=111, CV=44%; Slooten *et al.*, Submitted), genetically distinct from South Island populations (Pichler *et al.*, 1998) and occurs within a range that, according to sightings by researchers and the public, appears to have shrunk since 1990 (Russell, 1999). Both population viability analyses (Martien *et al.*, 1999) and analyses of genetic diversity (Pichler and Baker, 2000) indicate that the population is declining. Beachcast, net-marked carcases provide direct evidence of gillnet bycatch, which has been confirmed in recent interviews of fishermen (Sylvester, pers. comm.). While other impacts (e.g. trawling, pollution) may contribute, gillnet bycatch alone is sufficient to explain the decline. Continued gillnetting at recent levels is likely to result in the extinction of North Island Hector's dolphins within decades (Martien *et al.*, 1999).

MANAGEMENT OPTIONS AND THEIR EFFECTIVENESS

Establishment of Banks Peninsula Marine Mammal Sanctuary for Hector's dolphin

As mentioned above, the Banks Peninsula Marine Mammal Sanctuary was established in 1988 in an attempt to reduce the impact of gillnetting on Hector's dolphins. The sanctuary is an 1,170km^2 area, in which commercial gillnetting is illegal and amateur gillnetting is restricted. Amateur fishermen may still use gillnets, but only outside the summer months (November-February). Unattended gillnetting is permitted only for flounder, in specially designated areas in the innermost parts of the Peninsula's four largest harbours. Elsewhere within the sanctuary amateur fishermen must stay with their nets.

While it attracted significant controversy when first established, the sanctuary is now socially well accepted and has resulted in net financial benefits to the region. There are no data to test whether recreational fishing has improved, although this is sometimes stated. Hector's dolphins are now the focus of several dolphin-watching and dolphin-swimming businesses. When the sanctuary was first created it was estimated that its annual economic impact on commercial gillnet fishers was $NZ550,000 (Department of Conservation and Ministry of Fisheries, 1994). The largest of the dolphin-watching companies now turns over more than twice this figure annually (Bingham, pers. comm.).

While clearly a step in the right direction, the sanctuary is not enough to ensure the sustainability of the Canterbury Hector's dolphin population. Mark-recapture analysis of photo-ID data gathered before and after the sanctuary's creation show no trend of increased survival rates (Cameron *et al.*, 1999; DuFresne, 2004). A stochastic, age-structured population model (Slooten *et al.*, 2000) indicates that there is a 94% chance that this population is still in decline. This is most likely due to bycatch of animals outside the sanctuary's protection.

Incidental capture still occurs immediately north, south and offshore of the sanctuary in recreational and commercial gillnets, and there are occasional catches inside the sanctuary. The 1997/98 observer programme provides the best estimate (17) of current catch in commercial gillnets (Baird and Bradford, 2000; Starr, 2000). In the 2000/2001 summer, five dead dolphins bearing gillnet (4), or rope marks (1) were found beachcast along the beach of Pegasus Bay (4) or on the north side of Banks Peninsula (1). These mortalities were thought to be caused by amateur gillnetters (Department of Conservation and Ministry of Fisheries, 2001). A further dolphin was recovered from an amateur gillnet set in Pegasus Bay. It is likely that combined commercial and recreational gillnet bycatch for Canterbury is at least 15-30 animals per year. The lower end of this estimate is seven times greater than would be allowed using the PBR approach (Wade, 1998).

In May 2002, the Minister of Fisheries responded by extending the ban on recreational gillnetting from 1 October to 31 March and has extended the geographic boundaries north to the Waiau River (42°46.8'S, 173°22.4'E) and south to the Waitaki River (44°56.5'S, 171°08.5'E). The Minister also established a bycatch limit of three Hector's dolphins for this area, warning that this area would be closed to all gillnet fishing for the remainder of the year if the limit was exceeded (Hodgson, 2002). However, there is no formal bycatch monitoring for either recreational or commercial fishing.

North Island Hector's dolphin

In August 2001, the Minister of Fisheries closed a substantial section of the North Island west coast to gillnet fishing, to protect the critically endangered population of North Island Hector's dolphin (Maui's dolphin). This decision was successfully appealed by the fishing industry, and the ban on commercial fishing was lifted. However, after extensive discussions with stakeholders, in January 2003, the Minister again decided that closing a large area to gillnetting was the only option likely to reduce takes to sustainable levels. The protected area extends 210 n.miles (390km) alongshore from Maunganui Bluff to Pariokariwa Point (Fig. 1), to 4 n.miles offshore, and includes a small part of one of the harbours in which Hector's dolphins have been sighted. All fishing methods other than gillnetting (both commercial and recreational) are permitted in the area. The Minister is also considering placing observers on trawling and Danish seining vessels working off this coastline, to assess the entanglement risk posed by these two fishing practices. Planned research will address the proportion of time Hector's dolphins spend in west coast harbours, where gillnet fishing effort is high.

Use of pingers to reduce Hector's dolphin bycatch in Canterbury

In light of studies showing that pingers reduce entanglement rates of harbour porpoises (*Phocoena phocoena*) in New Hampshire gillnets (Kraus *et al.*, 1997), and that the mechanism appears to be avoidance of the ensonifed area (e.g. Gearin *et al.*, 2000), Stone *et al.* (1997) investigated the responses of Hector's dolphins to pingers. Hilltop observers documented surfacing positions in the vicinity of a moored pinger which was activated remotely without observers knowing. The study reported a statistically significant difference in dolphin distribution, and provided the foundation for the introduction of pingers by Canterbury gillnetters. As in several similar studies, however, the data

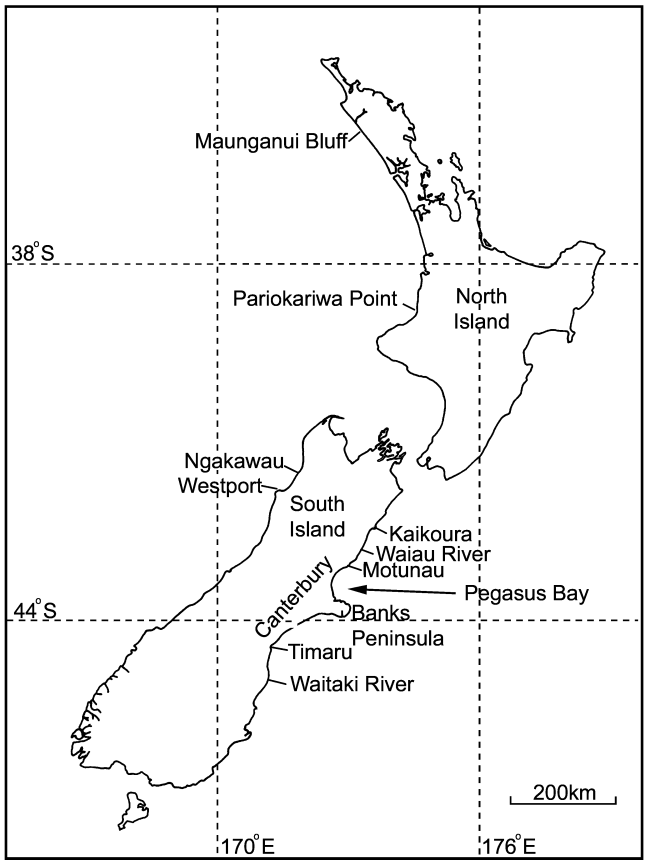

Fig. 1. Map showing place names mentioned in the text. The area closed to gillnetting from January 2003 is from Maunganui Bluff to Pariokariwa Point.

analysis suffered from pseudo-replication and the statistical result is unreliable (Dawson and Lusseau, 2005). Plots of surfacing positions (figs 3 and 4 in Stone *et al.*, 1997) show no clear avoidance of the pingers.

Nevertheless, Canterbury fishermen voluntarily use pingers under a 'Code of Practice' (Southeast Finfish Management Company, 2000) which, in addition to pinger use, encourages the setting of nets with the tide and the avoidance of setting nets in depths of less than 30m or when dolphins are around the vessel; it also advises on what might reasonably be considered best practice. In addition, some gillnetters have voluntarily shifted their fishing operations away from areas with high densities of Hector's dolphins.

It has been difficult, however, to ensure that pingers are used as required. While most of the skippers in the Canterbury gillnet fleet (Motunau to Timaru) have been co-operative, one refused to carry observers. Another insisted that it was dangerous for his crew member to attach pingers to the net as it is set. Since he believed that setting and hauling operations pose the greatest risk, he dangled pingers from his boat during these times. His nets, when set, were unalarmed. Of the 68 gillnet sets observed in Canterbury in 1999/2000, only 28% complied with the COP instructions for pinger deployment (Blezzard, pers. comm.). It is in the nature of fishermen to vary practices to find what seems the best solution, but this can mean that it is difficult to ensure effective use by everyone.

Without observers it is impossible to gain reliable data on entanglement and the effectiveness of pingers and other management measures. The organisers of the first observer programme in this fishery (1997/98) found it extremely difficult to gain a fleet coverage of 46% and 39% in the two statistical areas of primary interest (areas 20 and 22 respectively, Baird and Bradford, 2000; Starr, pers. comm.). Subsequently, coverage has been about 10% and 20% respectively in 1999/2000, approximately a third of that in 2000/2001 and there has been no coverage since this time.

It is impossible to say whether pingers are effective in reducing entanglements of Hector's dolphin, for two reasons. Firstly, because pingers are used in combination with several other measures intended to reduce entanglement rate, their effect (if any) is hidden. Secondly, there has been insufficient observer coverage to determine whether these measures, even in combination, are effective. In the 1997/98 fishing year, an observer programme detected 6 mortalities in gillnets from 214 sets (Baird and Bradford, 2000). Observer effort since then has been minimal (see above). One entanglement was observed in the 1999/2000 season, and the animal released alive. If we assume the simplest case of no area or season effects, bootstrapping can be used to judge the likelihood that the zero observed mortality in 1999-2001 is due to chance alone. Even when the two years with observer coverage are combined, there is a 14% chance that zero bycatches could be seen if the true bycatch rate is 6/214. Using power analysis the number of observed sets needed to detect any given reduction in this rate can be estimated (Dawson *et al.*, 1998). If a target of 80% reduction in bycatch is set and a nominal value of α=0.10 is accepted, it would take approximately 320 observed sets to detect a significant difference with 80% power.

As the power analysis shows, more observer coverage is needed to determine whether pingers significantly reduce incidental capture. Given that fishermen have implemented several changes simultaneously, it is difficult to determine the effectiveness of pingers. This unfortunately limits the guidance that can be offered to other fisheries which entangle Hector's dolphins.

Restrictions on surface set gillnetting at Kaikoura

With the aim of reducing bycatch of dusky dolphins, legislation now restricts the net height of gillnets set at the surface, and fishers must stay within 100m of the net. Possibly as a result of this rule, Kaikoura fishers appear to have stopped setting gillnets at the surface. Elsewhere in New Zealand, surface driftnets up to 1,000m are legal in the exclusive economic zone, but are rarely used.

FUTURE MANAGEMENT ACTIONS

Further closed areas

So far, two Hector's dolphin populations have been protected. One population is comparatively large (the Banks Peninsula population), while the other (North Island population) is very small and considered critically endangered. It makes sense to use a mixed conservation strategy, including large populations that provide good 'insurance' for the species' persistence, as well as preserving small, highly threatened populations. In this context it can be noted that gillnet fishing is used throughout the geographic range of Hector's dolphin, and the level of bycatch appears unsustainable for at least 10 of 16 local population subunits (Martien *et al.*, 1999).

To help mitigate mortality of New Zealand sea lions in the trawl fishery for arrow squid on the Auckland islands shelf, a Marine Mammal Sanctuary excludes all fishing within 12 n.miles of the shore (Slooten and Dawson, 1995). In 2003,

this area was reclassified as a no-take marine reserve. No protected areas have yet been created for other marine mammal species in New Zealand waters.

Limits on bycatch

An annual bycatch limit of three Hector's dolphins has been established for the Canterbury gillnet fishery (Hodgson, 2002). The limit is loosely based on the PBR formula used by NMFS (Wade, 1998). However, there are two problems with the way it has been calculated. Firstly, all Hector's dolphins on the South Island east coast have been considered as one stock, which we believe is unrealistic. Both movement (Brager *et al.*, 2002) and distribution data (Dawson and Slooten, 1988; Dawson *et al.*, 2004; Slooten *et al.*, 2004) suggest that in some cases a local population might be effectively isolated from others as little as 100km away. Secondly, the NMFS system uses a minimum estimate of population, which is defined as the lower 60% confidence interval of abundance. The Ministry of Fisheries limit is based instead on the point estimate of abundance.

Wade and Angliss (1997) suggest that if a species has small sub-populations with rare, low or moderate dispersal, the sub-populations should be split for the purposes of the US Marine Mammal Protection Act. If this suggestion is followed for Hector's dolphins, the area over which bycatch limits should apply would be small. Corresponding bycatch limits may thus be as little as fewer than one every several years in some cases. Without extremely high levels of observer coverage, it will be difficult to determine when the limit has been reached, with the possibility that the limit could be exceeded, perhaps substantially. In addition, given that observed catches could close the fishery, the very small bycatch limits would place great pressure on observers. For these reasons we believe that management via bycatch limits is impractical for Hector's dolphin.

EVALUATION OF EFFECTIVENESS OF MANAGEMENT MEASURES

Effectiveness of the Banks Peninsula Marine Mammal Sanctuary

Detecting change in population size or in population parameters (e.g. survival rate) is inherently difficult (e.g. Taylor and Gerrodette, 1993). This is especially so for dolphin populations, which are difficult to study, and whose low reproductive rates mean that population growth happens very slowly. Intensive population biology studies have been in place at Banks Peninsula since 1985. Adult survival rate is the most influential parameter in population models (Slooten and Lad, 1991; Slooten *et al.*, 2000). We expect our estimates of this parameter to gain precision with time, as the study continues, however, at this stage there is no indication that survival rates are increasing (DuFresne, 2004).

A lack of increasing survival rates is consistent with the fact that bycatch continues immediately north, south and offshore of the sanctuary (see above). Recent aerial surveys conducted in summer and winter (Slooten, Dawson and Rayment, unpublished data) indicate that in summer some 80% of the Banks Peninsula dolphins are found inside the sanctuary and in winter this drops to around 35%. In addition, occasional entanglements have occurred in gillnets set illegally inside the sanctuary by amateur fishermen. In this case it appears that the protected area is not large enough, and compliance with its restrictions is incomplete (Slooten *et al.*, 2000).

The extension, in time and geographic area, of the restrictions for recreational fishermen will help reduce bycatch mortality. If these new regulations are extended to commercial fishing, they may lead to a sustainable Hector's dolphin population in the Canterbury area.

ACKNOWLEDGMENTS

We are grateful to Sam DuFresne, Eduardo Secchi and Chris Richter for many discussions and for comments on the manuscript. Participation in the Department of Conservation 'Conservation Services Programme' and Ministry of Fisheries 'Aquatic Environment Working Group' has provided an insider's view on management issues. We thank Ian West and Reg Blezard for the observer data. Two reviewers provided helpful comments. Steve Dawson thanks the Istituto Centrale per la Ricerca scientifica e tecnologica Applicata al Mare for inviting him to a workshop on dolphin interactions with gillnets in Rome in 2001.

REFERENCES

Baird, S.J. and Bradford, E. 2000. Estimation of the total bycatch of Hector's dolphins (*Cephalorhynchus hectori*) from the inshore trawl and setnet fisheries off the east coast of the South Island in the 1997-98 fishing year. Published Client Report on contract 3024, funded by Conservation Services Levy. Department of Conservation, Wellington. 28pp. [Available at: *http://csl.doc.govt.nz/CSL3024.pdf*].

Baker, A.N., Smith, A.N.H. and Pichler, F.B. 2002. Geographical variation in Hector's dolphin: recognition of new subspecies of *Cephalorhynchus hectori*. *J. R. Soc. NZ* 32(4):713-27.

Batkin, K.M. 1996. New Zealand's quota management system: a solution to the United States' federal fisheries management crisis? *Natural Resource Journal* 36(4):855-80.

Bjørge, A., Brownell, R.L.J., Donovan, G.P. and Perrin, W.F. 1994. Significant direct and incidental catches of small cetaceans. A report by the Scientific Committee of the International Whaling Commission to the United Nations Conference on Environment and Development (UNCED). *Rep. int. Whal. Commn* (special issue) 15:75-130.

Bräger, S., Dawson, S.M., Slooten, E., Smith, S., Stone, G.S. and Yoshinaga, A. 2002. Site fidelity and along-shore range in Hector's dolphin, an endangered marine dolphin from New Zealand. *Biol. Conserv.* 108:281-7.

Cameron, C., Barker, R., Fletcher, D., Slooten, E. and Dawson, S. 1999. Modelling survival of Hector's dolphins around Banks Peninsula, New Zealand. *J. Agric. Bio. Env. Stat.* 4:126-35.

Clark, I.N., Major, P.J. and Mollett, N. 1988. Development and implementation of New Zealand's ITQ management system. *Marine Resource Economics* 5:325-49.

Darby, J.T. and Dawson, S.M. 2000. Incidental bycatch of yellow-eyed penguins (*Megadyptes antipodes*) in gillnets in New Zealand waters 1979-1997. *Biol. Conserv.* 93(3):327-32.

Dawson, S.M. 1991. Incidental catch of Hector's dolphin in inshore gillnets. *Mar. Mammal Sci.* 7(3):118-37.

Dawson, S.M. and Lusseau, D. 2005. Pseudoreplication problems in studies of dolphin and porpoise reactions to pingers. *Mar. Mammal Sci.* 21(1):175-6.

Dawson, S.M. and Slooten, E. 1988. Hector's dolphin, *Cephalorhynchus hectori*: distribution and abundance. *Rep. int. Whal. Commn* (special issue) 9:315-24.

Dawson, S.M. and Slooten, E. 1993. Conservation of Hector's dolphins: The case and process which led to the establishment of the Banks Peninsula Marine Mammal Sanctuary. *Aquat. Conserv.* 3:207-21.

Dawson, S.M., Read, A. and Slooten, E. 1998. Pingers, porpoises and power: uncertainties with using pingers to reduce bycatch of small cetaceans. *Biol. Conserv.* 84:141-6.

Dawson, S.M., Slooten, E., Pichler, F., Russell, K. and Baker, C.S. 2001. North Island population of Hector's dolphin threatened with extinction. *Mar. Mammal Sci.* 17(2):366-71.

Dawson, S.M., Slooten, E., DuFresne, S.D., Wade, P.R. and Clement, D. 2004. Small-boat surveys for coastal dolphins: line-transect surveys of Hector's dolphins. *Fish. Bull.* 201:441-51.

Department of Conservation and Ministry of Fisheries. 1994. Review of the Banks Peninsula Marine Mammal Sanctuary: a paper for public comment. Department of Conservation, Christchurch. 25pp. [Available from: *publ.doc.govt.nz*].

Department of Conservation and Ministry of Fisheries. 2001. Hector's dolphin and set netting Canterbury area: a paper for public comment – June 2001. 10pp. [Available from New Zealand Ministry of Fisheries, Marine Conservation Unit, PO Box 10-420, Level 5, 53 Boulcott Street, Wellington, NZ].

DuFresne, S.J. 2004. Conservation biology of Hector's dolphin. Ph.D. Thesis, University of Otago. 152pp.

Gearin, P.J., Gosho, M.E., Laake, J., Cooke, L., Delong, R.L. and Hughes, K.M. 2000. Experimental testing of acoustic alarms (pingers) to reduce bycatch of harbour porpoise, *Phocoena phocoena*, in the state of Washington. *J. Cetacean Res. Manage.* 2(1):1-10.

Hall, M.A. and Donovan, G.P. 2002. Environmentalists, fishermen, cetaceans and fish: is there a balance and can science find it? pp. 491-521. *In:* P.G. Evans and J.A. Raga (eds.) *Marine Mammals: Biology and Conservation*. Kluwer Academic/Plenum Publishers, New York.

Hembree, D. and Harwood, M.B. 1987. Pelagic gillnet modification trials in northern Australian seas. *Rep. int. Whal. Commn* 37:369-73.

Hodgson, P. 2002. South Island Hector's dolphin decisions. Ministry of Fisheries, PO Box 1020, Wellington, NZ. 13pp.

International Whaling Commission. 2000. Report of the Scientific Committee. Annex I. Report of the Sub-Committee on Small Cetaceans. *J. Cetacean Res. Manage. (Suppl.)* 2:235-57.

Kraus, S.D., Read, A.J., Solow, A., Baldwin, K., Spradlin, T., Anderson, E. and Williamson, J. 1997. Acoustic alarms reduce porpoise mortality. *Nature, Lond.* 388:525.

Martien, K.K., Taylor, B.L., Slooten, E. and Dawson, S.M. 1999. A sensitivity analysis to guide research and management for Hector's dolphin. *Biol. Conserv.* 90:183-91.

Murray, K.T., Read, A.J. and Solow, A.R. 2000. The use of time/area closures to reduce bycatches of harbour poporises: lessons from the Gulf of Maine sink gillnet fishery. *J. Cetacean Res. Manage.* 2(2):135-41.

Peacey, J. 1996. The New Zealand seafood industry economic review 1994-1996. NZ Fishing Industry Board, PO Box 24901, Wellington, NZ. 65pp.

Perrin, W.F., Donovan, G.P. and Barlow, J. (eds.). 1994. *Report of the International Whaling Commission (Special Issue 15). Gillnets and Cetaceans*. International Whaling Commission, Cambridge, UK. 629pp.

Pichler, F. and Baker, C.S. 2000. Loss of genetic diversity in the endemic Hector's dolphin due to fisheries-related mortality. *Proc. R. Soc. Lond. Ser. B.* 267:97-102.

Pichler, F.B., Dawson, S.M., Slooten, E. and Baker, C.S. 1998. Geographic isoloation of Hector's dolphin populations described by mitochondrial DNA sequences. *Conserv. Biol.* 12:676-82.

Read, A.J., Van Waerebeek, K., Reyes, J.C., McKinnon, J.S. and Lehman, L.C. 1988. The exploitation of small cetaceans in coastal Peru. *Biol. Conserv.* 46:53-70.

Russell, K. 1999. The North Island Hector's dolphin: a species in need of conservation. MSc Thesis, University of Auckland. 137pp.

Secchi, E.R. and Wang, J.Y. 2002. Assessment of the conservation status of a fransiscana (*Pontoporia blainvillei*) stock in the fransiscana management area III following the IUCN Red List process. *The Latin American Journal of Aquatic Mammals* 1(1 – Special Issue on the Biology and Conservation of the Franciscana):183-90.

Slooten, E. and Dawson, S.M. 1995. Conservation of New Zealand marine mammals. *Pacific Conservation Biology* 2(1):64-76.

Slooten, E. and Lad, F. 1991. Population biology and conservation of Hector's dolphin. *Can. J. Zool.* 69:1701-7.

Slooten, E., Dawson, S.M. and Lad, F. 1992. Survival rates of photographically identified Hector's dolphins from 1984 to 1988. *Mar. Mammal Sci.* 8(4):327-43.

Slooten, E., Fletcher, D. and Taylor, B. 2000. Accounting for uncertainty in risk assessment: case study of Hector's dolphin mortality due to gillnet entanglement. *Conserv. Biol.* 14:1264-70.

Slooten, E., Dawson, S.M. and Rayment, W.J. 2004. Aerial surveys for coastal dolphins: Abundance of Hector's dolphins off the South Island West Coast, New Zealand. *Mar. Mammal Sci.* 20(3):477-90.

Slooten, E., Dawson, S.M., Rayment, W.J. and Childerhouse, S.J. Submitted. Maui's dolphin may be the rarest marine mammal. 12pp. [Submitted to: *Marine Mammal Science*].

Southeast Finfish Management Company. 2000. Voluntary Code of Practice – Commercial net setters. SE Finfish Management Ltd, PO Box 43, Lyttelton, NZ. 22pp.

Starr, P. 2000. Comments on "Estimation of the total bycatch of Hector's dolphins (*Cephalorhynchus hectori*) from the inshore trawl and setnet fisheries off the east coast of the South Island in the 1997-98 fishing year". Paper presented to Conservation Services Levy Working Group. Department of Conservation, Wellington, New Zealand (unpublished). 4pp.

Starr, P. and Langley, A. 2000. Inshore fishery observer programmes for Hector's dolphins in Pegasus Bay, Canterbury Bight, 1997/98. Department of Conservation, Wellington. 28pp. [Available from: *http://csl.doc.govt.nz/CSL3020.pdf*; Published client report on contract 3020, funded by Conservation Services Levy].

Stone, G., Kraus, S., Hutt, A., Martin, S., Yoshinaga, A. and Joy, L. 1997. Reducing bycatch: Can acoustic pingers keep Hector's dolphins out of fishing nets? *Mar. Technol. Soc. J.* 31(2):3-7.

Taylor, B.L. and Gerrodette, T. 1993. The uses of statistical power in conservation biology: the vaquita and northern spotted owl. *Conserv. Biol.* 7(3):489-500.

Taylor, B.L. and Rojas-Bracho, L. 1999. Examining the risk of inbreeding depression in a naturally rare cetacean, the vaquita (*Phocoena sinus*). *Mar. Mammal Sci.* 15(4):1004-28.

Van Waerebeek, K., Van Bressem, M.-F., Alfaro-Shigueto, J., Sanino, G.P., Montes, D. and Ontón, K. 1999. A preliminary analysis of recent captures of small cetaceans in Peru and Chile. Paper SC/51/SM17 presented to the IWC Scientific Committee, May 1999, Grenada, WI (unpublished). 14pp. [Paper available from the Office of this Journal].

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

Wade, P.R. and Angliss, R.P. 1997. Guidelines for assessing marine mammal stocks: Report of the GAMMMS Workshop April 3-5, 1996, Seattle, Washington. NOAA Technical Memorandum NMFS-OPR-12. 93pp. [Available from *http://www.nmfs.noaa.gov/publications.htm*].

Würsig, B., Cipriano, F., Slooten, E., Constantine, R., Barr, K. and Yin, S. 1997. Dusky dolphins (*Lagenorhynchus obscurus*) off New Zealand: status of present knowledge. *Rep. int. Whal. Commn* 47:715-22.

Date received: March 2004.
Date accepted: November 2004.