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## Short communication

# A new abundance estimate for Maui's dolphin: What does it mean for managing this critically endangered species?

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## ABSTRACT

Hector's dolphin *Cephalorhynchus hectori* is found only in New Zealand waters. We carried out a population survey of the North Island subspecies *Cephalorhynchus hectori maui*, also known as Maui's dolphin. The total population size estimate is 111 individuals (95% confidence interval = 48–252). The small population size confirms its critically endangered IUCN status. A sustainable level of human-caused mortality for this population would be 0.16 (one dolphin every 6.4 years). This essentially means that fisheries bycatch, and where possible other human impacts, need to be eliminated to allow population recovery. A protected area has been created to reduce the threat from entanglement in fishing gear. Gillnet fishing is prohibited along a 210 nautical mile stretch of coastline. The main concerns are that gillnet fishing is still allowed inside harbours and trawling continues inside the protected area.

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## 1. Introduction

Hector's dolphin *C. hectori* is a small, coastal delphinid restricted to the inshore waters of New Zealand. Studies of mtDNA and microsatellite variation indicate at least four separate populations (North Island west coast, South Island west, east and south coasts; Pichler et al., 1998; Pichler and Baker, 2000; Pichler, 2002). Total abundance of the three South Island populations is estimated at 7270 (CV = 16.2%; Dawson et al., 2004; Slooten et al., 2004). Differences in skull morphology and haplotypes, and low levels of gene flow have led to designation of the North Island population as a separate subspecies *C. h. maui* (Baker et al., 2002). Recent sightings of *C. h. maui* (known as North Island Hector's dolphin, Maui's dolphin

or Popoto) are restricted to the close inshore zone of the North Island's west coast, between Dargaville (35°59'S, 173°46'E) and New Plymouth (39°03'S, 174°00'E; Dawson et al., 2001).

A declining population is indicated by: (a) apparent contraction in alongshore range over the last 20 years based on population surveys (Russell, 1999), (b) decline in the number of mtDNA lineages present in current genetic samples (Pichler and Baker, 2000), (c) analyses of the level of bycatch in fishing operations showing that gillnet bycatch, by itself, is unsustainable (Martien et al., 1999; Burkhart and Slooten, 2003) and (d) continuing discovery of gillnet-marked Maui's dolphin carcasses (e.g. Dawson et al., 2001). Interviews with fishers (Russell and Sylvester, pers. comm.) also provided evidence of Maui's dolphin bycatch in gillnet and trawl fisheries.

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Considering the above, a robust estimate of current abundance is urgently needed.

Given the gap in geographic distribution and genetic differences between North and South Island populations, it is extremely unlikely that individuals removed from the North Island population (e.g. through bycatch) would be replaced by individuals from the South Island. In an attempt to halt the population decline a protected area was created in 2003 between Maunganui Bluff and Pariokariwa Point, about 24 nm (44.5 km) north of New Plymouth (see Fig. 1). Along this 210 nm (389 km) stretch of coastline, gillnet fishing is prohibited out to 4 nm (7.4 km) offshore but is still allowed inside harbours. In addition, trawling continues inside the protected area. Unfortunately, there is no observer programme and no quantitative data on continued impacts. However, continued trawling and illegal gillnetting in the protected area and continued discovery of gillnet-marked Maui's dolphin carcasses indicates that bycatch continues.

We carried out a line-transect survey to estimate population size (Buckland et al., 2001). A current abundance estimate is essential in order to provide advice on conservation status and sustainable limits for human impacts on the species (e.g. Huang et al., 2002; Kinnaird et al., 2003). Line-transect methods are commonly used for such surveys (e.g. Harlow and Bickiloa, 2001; Kinnaird et al., 2003).

## 2. Methods

Between 14 and 28 January 2004 we carried out an intensive line-transect aerial survey to assess distribution and abundance of Maui's dolphins. Transect lines were placed at 45° to the shore, spaced one nautical mile (nm = 1.853 km) apart in the central stratum and 2 nm apart in the northern and southern strata, and extended out to 5 or 10 nm offshore (Fig. 1). Transect lines were flown at 100 knots (185.3 km/h)

at a height of 500 ft (152.4 m) in a Partenavia P68 aircraft with four observers. Further details on field protocol can be found in Slooten et al. (2004).

Observations from a Robinson R22 helicopter during 29–31 January were used to quantify *availability* bias, the proportion of time that Maui's dolphins are available to be counted from the survey height. There was no indication that the helicopter (at the height and distance flown) affected dolphin behaviour or dive durations. No observations were made from the helicopter that were in any way inconsistent with behaviour and dive duration observations made from boats and cliff-top observation sites (e.g. Slooten, 1994; Slooten and Dawson, 1994). Availability is often assessed by estimating the proportion of time animals spend at the water surface (e.g. Barlow et al., 1988; Laake et al., 1997). Observations of dive patterns from cliff-top vantage points (Laake et al., 1997) could have biased the results by excluding individuals found further offshore. Observations from boats or time-depth recorders would have failed to replicate sighting conditions on an aerial survey. Helicopter observations made it possible to estimate the proportion of time the animals were visible at or just below the water surface, as seen from the air at the same height that the survey transects were flown.

Perception bias, the probability of counting a dolphin group at the surface on the trackline, is usually estimated by using two teams of observers either on the same boat (e.g. Palka, 1995) or aircraft (e.g. Manly et al., 1996), or on separate platforms (e.g. Carretta et al., 1998). In this aerial survey, we used data from the front and rear observers in a modified mark-recapture approach to estimate perception bias (Slooten et al., 2004; Manly et al., 1996), based on the proportion of sightings made by one observer but not the other. Data analysis followed Manly et al. (1996), correcting for the proportion of missed sightings by fitting a logistic curve to data from two independent observers. Variables assumed to influence

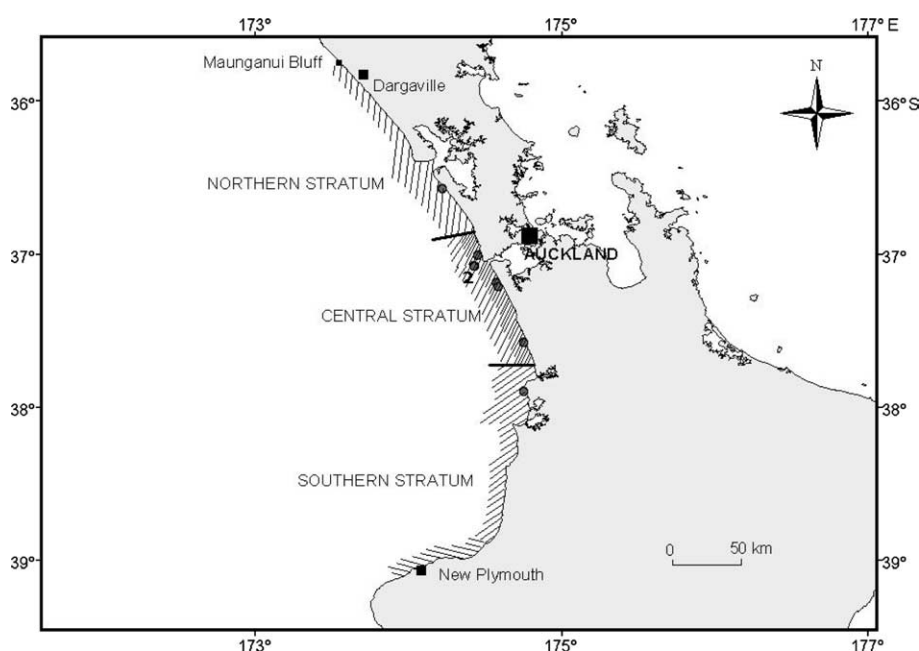


Fig. 1 – Map of New Zealand's North Island west coast, showing transect lines surveyed and sightings. The "2" indicates two sightings in close proximity to each other.

detection probability included observer position, dolphin group size and distance from the trackline. Five models were fitted using maximum likelihood (Manly et al., 1996), from a simple model in which detection probability was the same for front and rear seat observers and not affected by either distance from the trackline or group size, to a complex model in which probability of detection is different for the two observer positions and depends on both distance from the trackline and group size. Best models were chosen using Akaike's information criterion (AIC; Akaike, 1973). Please see Slooten et al. (2004) and Manly et al. (1996) for further details of this analysis. The probability of recording a sighting on the trackline,  $g(0)$ , was calculated as the product of the estimates of perception bias and availability bias.

Survey and analysis protocols followed Slooten et al. (2004). The key difference was that sample size for estimation of effective strip width was increased by combining sightings from this survey with those from our immediately previous survey of Hector's dolphins at Banks Peninsula on the east coast of the South Island. The Banks Peninsula survey was conducted using the same aircraft and observers, and used identical protocols. Sighting conditions (including mean sea state and water clarity) were very similar at Banks Peninsula and off the North Island west coast.

### 2.1. Abundance estimation

The standard form of the line-transect equation for abundance ( $N$ ) is

$$N = \frac{AnS}{2LESWg(0)}, \quad (1)$$

where,  $A$  = size of the study area,  $n$  = number of groups seen,  $S$  = average group size,  $L$  = length of transect line surveyed,  $ESW$  = the effective half strip width, and  $g(0)$  = probability of seeing a group directly on the transect line.

Group size and effective strip width were estimated globally, with encounter rate and density estimated by stratum. Modelling of effective strip width was done using Distance 4.1. software (Thomas et al., 2003), allowing the software to choose candidate models via AICs. In using bootstrapping to incorporate model uncertainty into estimation of effective strip width we noted that some replicates produced estimates of effective strip width that were clearly outliers. In each case the same model was selected (Hazard/first-order Cosine) which appeared to be performing poorly when bootstrap replicates were spiked (which is likely when bootstrapping from a reasonably small sample of observations;  $n = 47$ ). To avoid this problem, but still incorporate model uncertainty, we made a subset of all models within two AIC units of the best model (i.e. AIC range 561–563; Burnham and Anderson, 2002) and specified these manually in Distance, requiring 1000 replicate bootstrap resampling of the original observations. The models specified were Hazard, half-normal, half-normal/second-order cosine, Uniform/first-order cosine and half-normal/fourth-order hermite. All other calculations were performed outside Distance. The CV of encounter rate was calculated (separately for each stratum) from 1000 bootstrap resamples of the original transects.

The CV of the abundance for each stratum was calculated from the coefficients of variation of each variable element:

$$CV(N) = \sqrt{\{CV^2(n/L) + CV^2(S) + CV^2(ESW) + CV^2[g(0)]\}}. \quad (2)$$

The CV of the combined stratum estimates (i.e. the total population) was calculated via:

$$SE(\text{total}) = \sqrt{\{SE^2(N1) + SE^2(N2) + SE^2(N3)\}} \quad (3)$$

and

$$CV(\text{total}) = SE(\text{total})/N(\text{total}). \quad (4)$$

## 3. Results and discussion

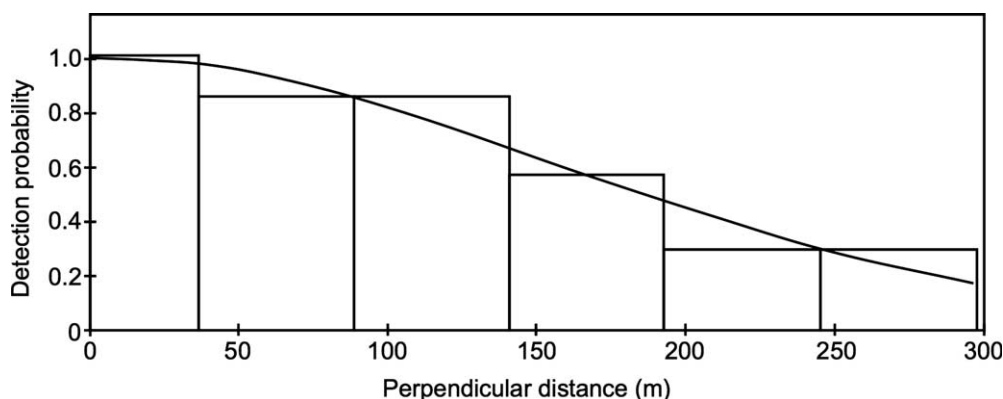
In 1919 km of sighting effort (112 transects), we made eight sightings of Maui's dolphins on transect lines: six in the central stratum and one each in the northern and southern strata (Table 1, Fig. 1). Because none of the sightings was beyond 5 nm (9.3 km) offshore, we used the area out to 5 nm for abundance calculations. To increase sample size for estimation of effective strip width we combined sightings from the North Island survey ( $n = 8$ ) with those from a survey ( $n = 42$ ) at Banks Peninsula carried out immediately before the North Island survey (6–13 January 2004) using the same observers and methods. Following Buckland et al. (2001), 5% of the sightings furthest from the trackline were removed from the dataset before fitting the detection function. This meant eliminating sightings beyond a perpendicular distance of 297 m, leaving a total of 47 sightings for estimating effective strip width (Fig. 2). The probability of counting a dolphin group at the surface on the trackline (0.994;  $CV = 1.2\%$ ) was estimated on the basis of 20 sightings from the North Island and Banks Peninsula surveys combined (Table 2). AIC values indicated that the probability function for making a sighting depended on observer position and distance from the trackline, and depended on group size in the same way for front- and rear-seat observers. Helicopter-based observations of 186 dive/surface cycles by 21 Maui's dolphin groups showed that dolphins were near the water surface and available to be counted 55.6% of the time ( $CV = 6.0\%$ , Table 2). Average group size in the North Island survey was 1.43 ( $CV = 20.8\%$ ).

The total abundance estimate for Maui's dolphins between Maunganui Bluff (35°45.6'S, 173°32.8'E) and New Plymouth (39°7.26'S, 174°54.7'E) is 111 individuals ( $CV = 44\%$ ). The log-normal 95% confidence interval (Buckland et al., 2001) is 48–252. This confirms the IUCN's decision to list this sub-species separately as critically endangered, while listing the species as a whole as endangered (IUCN, 2004). The Maui's dolphin

**Table 1 – Stratum areas, survey intensity and number of sightings**

Stratum (to 5 nm [9.26 km] offshore)	North	Central	South
Area (km <sup>2</sup> )	1440.03	994.94	1941.75
Transect spacing (km)	3.7	1.85	3.7
Line length (km)	376.05	514.06	496.27
No. sightings <sup>a</sup>	1	5	1

a After truncation at 297 m.



**Fig. 2 – Histogram of perpendicular sighting distances (n = 47) gained at Banks Peninsula (6–13 January 2004) and on transects shown in Fig. 1 (14–28 January 2004). The fitted curve is a half-normal function with no adjustments. Sighting distances were truncated at 297 m.**

population has been reduced to less than 30% of its original size by gillnet bycatch since 1970 (Martien et al., 1999; Burkhart and Slooten, 2003). Population recovery will be slow and far from certain, given the strong influence of demographic stochasticity in small and fragmented populations (e.g. Lande, 1988; Pimm, 1991; Harlow and Bicilola, 2001). In a Hector’s dolphin population of ≈111 individuals, one would expect there to be no more than 56 females and no more than 28 mature females (IUCN, 2004).

Although a powerful trigger for conservation action, estimates of historical population size may not be appropriate targets for recovery (Marsh et al., 2005). For example, the historical population level may not be achievable due to changes in the carrying capacity of the habitat (Marsh et al., 2005). In addition, it can be very difficult to determine whether and at what rate the population is recovering, especially for very small populations (e.g. Taylor and Gerodette, 1993). Instead, it may be more productive to set targets for sustainable levels of human-caused mortality using the potential biological removal (PBR) method (Wade, 1998). This method is not recommended for very small populations, that are at risk of extinction through stochastic processes including demographic and environmental stochasticity (Wade, 1998). For very small populations, Wade (1998) suggests carrying out a more detailed population viability analysis (Gilpin and Soulé, 1986; Slooten et al., 2000; Burkhart and Slooten, 2003). However, even in these cases, a PBR calculation can provide an assessment of the importance of known sources of human-caused mortality as well as general guidance for managing impacts. A PBR for Maui’s dolphin would be 0.16 (one dolphin every 6.4 years). Parameters in this calculation are:  $N_{min}$  (lower 60% confidence

interval of abundance estimate) = 78,  $R_{max}$  (maximum population growth rate, default value for dolphins) = 4%, recovery factor (default value for endangered species) = 0.1 (Wade, 1998). Following discussion of the PBR for Maui’s dolphin, the consensus at a stakeholder meeting (attended by government agencies, fishers, independent scientists and NGOs) was that human impacts need to be reduced to zero.

Managers in the US drew a similar conclusion for North Atlantic right whales *Eubalaena glacialis*. Given the small population size (estimated at just below 300) and impacts from fisheries bycatch and ship collisions, managers decided to set a PBR of zero for fishing impacts (Waring et al., 2002). Clearly, with a population of just over 100 Maui’s dolphins, fisheries bycatch, and where possible other human impacts, must be eliminated to allow population recovery.

Two management actions that would have an immediate benefit would be to prohibit trawling inside the protected area and gillnetting inside the harbours adjacent to the protected area. Part of the Manukau Harbour is included in the protected area, however the other harbours are excluded. Maui’s dolphins use at least three of the five harbours on the west coast North Island (Russell in litt.; Slooten et al., 2005). Preliminary results from a study using acoustic data loggers (PODs or Porpoise Detectors; Tregenza, 2002) show that Maui’s dolphins regularly enter the Manukau Harbour and travel beyond the boundary of the protected area (Richlen et al. in litt.). The level of bycatch in the local trawl fishery is not known, but bycatch of Hector’s dolphins has been observed in South Island trawl fisheries (Starr and Langley, 2000).

Several other coastal cetaceans have small and apparently declining populations (Perrin et al., 1994; Reeves, 2002). Assessment of these populations is urgent. This survey indicates that, given suitable survey design and sampling intensity, aerial line-transect methods can be successful even at extremely low dolphin densities.

**Table 2 – Parameters estimated globally**

Parameter	Estimate	CV	n
Effective strip width <sup>a</sup> (km)	0.203	0.262	47
Average group size <sup>a</sup>	1.429	0.208	7
Availability bias	0.556	0.060	186
Perception bias	0.994	0.012	20

<sup>a</sup> After truncation at 297 m.

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