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Effectiveness of partial protection for Mauis dolphin

Elisabeth Slooten

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Elisabeth Slooten, University of Otago, P.O. Box 56, Dunedin, New Zealand

ABSTRACT

An individual-based model was used to compare the estimated rate of population decline for Maui's dolphin *(Cephalorhynchus hectori mauii)* under three different scenarios: 1. Past fisheries regulations, 2. Current fisheries regulations and 3. Protection measures recommended by the International Whaling Commission (IWC). Two extensions to the protection measures were implemented in 2012 and 2013, with the aim of halting population decline. However population declines continue under option 2. The probability of depletion to ≤ 10 individuals has improved from 58% to 48% compared to 0% for option 3. The probability of depletion to ≤ 30 individuals is 98% under option 1, 97% under option 2 and 12% under option 3. Implementing the IWC recommendation to extend protection south to Whanganui and offshore to 20 nautical miles (nmi) would improve the probability of population recovery from 0% to 40%. This analysis only considers fisheries mortality. Other potential impacts such as pollution, oil and gas exploration and production were not included.

INTRODUCTION

Maui's dolphin *Cephalorhynchus hectori mauii* is the North Island subspecies of Hector's dolphin *Cephalorhynchus hectori*. The species as a whole (both subspecies) is known as New Zealand (NZ) dolphin. Bycatch in gillnet and trawl fisheries is the greatest source of human impact (e.g. DOC & Mfish 2007; MPI & DOC 2012; Currey et al. 2012). Maui's dolphins are partially protected from gillnets and trawl nets. All other fishing methods, including fish traps, hook and line methods, can be used throughout NZ dolphin habitat.

This paper presents a quantitative analysis of the level of protection for Maui's dolphin from this partial protection of its habitat. The analysis considers the proportion of habitat protected as well as the amount of movement, of both dolphins and the human activities that pose a threat to their survival. The agent based modelling platform Netlogo was used for this analysis. It allows the use of both moving and stationary threats, with dolphins moving through an environment which is partially protected. Instead of applying an average level of human impact uniformly to the entire population, individual dolphins move into and out of areas with different levels of protection, interacting with gillnets and trawl nets in those parts of their habitat that are unprotected.

The effectiveness of two extensions to Maui's dolphin protection, implemented in 2012 and 2013, was quantified. In addition, the effectiveness of current management is compared with the level of protection recommended by the International Whaling Commission (IWC) in 2012, 2013 and 2014 (e.g. IWC 2013, 2014).

MATERIALS AND METHODS

The analysis was carried out using Netlogo (version 5.1.0) an agent based modelling platform dowloadable from the Netlogo webpage (Wilenski 1999). The model was parameterized using empirical data from a long-term research programme on Hector's and Maui's dolphin (e.g. Gormley et al. 2012; Slooten 2013; Slooten et al. 2000, 2004, 2005, 2006; Slooten and Lad 1992) and government data on fisheries mortality (DOC & Mfish 2007; MPI & DOC 2012; Baird et al. 2015; Currey et al. 2012; Davies et al. 2008; Penny et al. 2007). The biological dataset includes population surveys and estimates of movement, survival and reproductive rates. The fisheries data include estimates of fishing effort, catch rates and movements of fishing vessels. Additional information about the data used for each input into the model is provided below.

Spatial structure

The model was set up to represent the habitat of Maui's dolphin and the relevant fishing regulations (Fig. 1). In the northern part of Maui's dolphin's range, protection implemented in 2008 prohibits gillnetting to 7 nmi offshore and trawling to a maximum of 4 nmi offshore. In 2012 and 2013 the protected area was extended further south. The gillnet ban to 7 nmi offshore (but not the trawl ban to 4 nmi) was extended south to New Plymouth. The gillnet ban was further extended south to Hawera, but in this southern part of the protected area gillnets are banned to 2 rather than 7 nmi offshore. The southern part of the Maui's dolphin range, from Hawera to Whanganui remains unprotected. The modeled dolphin habitat extends to 20 nmi offshore.

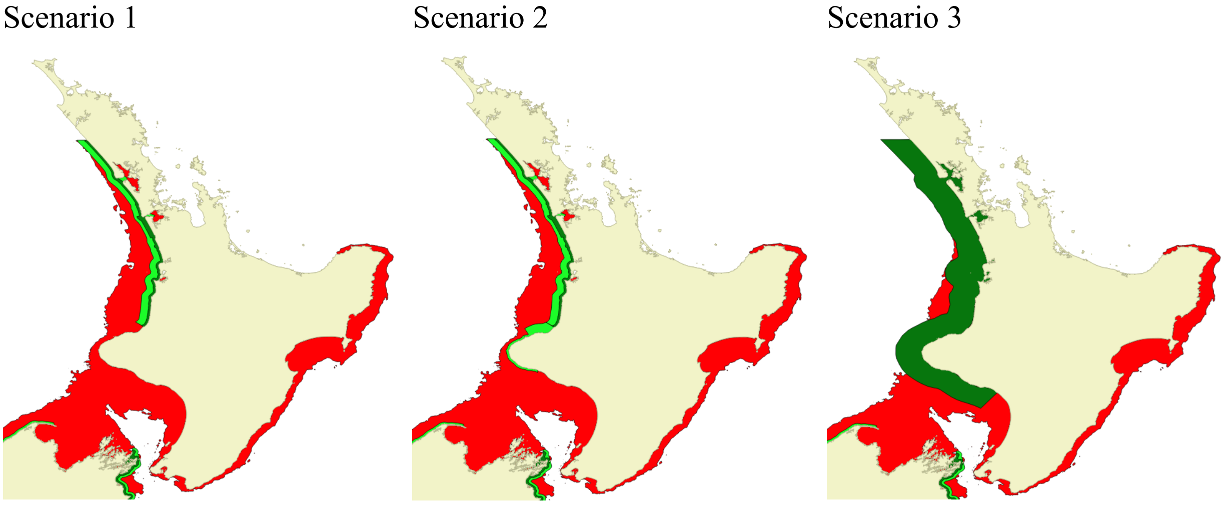

Figure 1. Protected area in 2012 (scenario 1), in 2014 (scenario 2) and recommended by the IWC (scenario 3). Red: Range of NZ dolphin (100m depth contour). Dark green: Areas where gillnets and trawling are banned. Light green: Areas where gillnets are banned but trawling is permitted.

Dolphins ranged throughout the area, with preference for inshore waters based on data from population surveys with equal survey effort with respect to distance from shore (Slooten et al. 2004, 2006; Rayment and du Fresne 2007; Childerhouse et al. 2008). Gillnets were stationary and allocated using estimates of fishing effort from the Ministry for Primary Industries (e.g. Currey et al. 2012). Gillnets were placed in a new location each day, to represent typical fishing behaviour. Gillnets are usually cleared every 24-48 hours and then put back in the water. Trawling vessels were modelled as moving agents, with a movement rate corresponding to the average distance over which trawling vessels deploy their trawl gear (approx. 8 nmi per day; Baird et al. 2015). Gillnet and trawling effort were restricted to areas where these fishing methods are legal, i.e. the model does not take account of illegal fishing.

Bycatch

The number of trawlers and gillnets off the North Island west coast was based on the number of fishers in Penny et al. (2007), the amount of fishing effort reported in Currey et al. (2012) and the amount of trawl effort per day reported by Baird et al. (2015). Penny et al. (2007) estimated that 3 fishers in this area catch > 6% of their total catch in gillnets, with one fisher catching more than 20% of his catch using gillnets. They estimated that there were 104 additional fishers who use gillnets but catch only 1-5% of their catch this way. Penny et al. (2007) estimated that 4.6% of the total fish catch off the North Island west coast (by weight) is caught in gillnets. These estimates indicate that there are approximately 10 commercial gillnets in the water off the North Island west coast at any one time.

Penny et al. (2007) estimated that 4 of the inshore fishers in this area catch > 6% of their total catch using trawl gear, with two fishers catching more than 20% of their catch using trawling. They estimated that there were 19 additional fishers who use trawl gear but catch only 1-5% of their catch this way. Penny et al. (2007) estimated that 20% of the total fish catch off the North Island west coast (by weight) is caught by inshore trawlers. Based on these estimates, one would expect approximately 5 trawlers to be operating in inshore waters of the North Island west coast at any one time. There have been changes in the areas where gillnets and trawling are allowed to be used since Penny et al. (2007) carried out their interviews. However, these two fishing methods have been banned in relatively small areas. Experience in other areas (e.g. east coast of South Island) indicates that all or most of this fishing effort would have been displaced to unprotected areas (e.g. Slooten and Davies 2011) rather than removed from the fishery (e.g. by fishers changing to other fishing methods).

In this spatially explicit analysis, the catch rate describes the probability of a dolphin death for any given dolphin that encounters a gillnet or trawl net. Past observer programmes do not explicitly estimate this parameter. However, a bycatch rate of 0.1 for gillnets and 0.05 for trawling is consistent with existing bycatch estimates (DOC & Mfish 2007; MPI & DOC 2012; Currey et al. 2012; Baird & Bradford 2000; Davies et al. 2008; Davies and Slooten 2011).

Current protection is compared with the level of protection up to 2012, in order to quantify the effectiveness of the two protected area extensions in 2012 and 2013. The third scenario quantifies the effectiveness of the protection measures recommended by the IWC.

Reproduction, natural mortality and starting population size

The analysis used the most optimistic estimate of reproductive rate for NZ dolphins, expected in the absence of intra-specific competition or an Allee Effect, with females starting to breed at age seven and producing one calf every two years (Slooten and Lad 1991; Slooten et al. 2000). Likewise, the model used an optimistic level of natural mortality, using the mortality curve for humans from Slooten and Lad (1992), scaled to a lifespan of 30 years following Barlow and Boveng's (1991) approach. These reproductive and mortality rates are appropriate, given the very small size of the Maui's dolphin population.

Very small populations can experience lowered rates of increase due to a variety of factors, including inbreeding, difficulty in finding mates, reduced effectiveness of predator-defense due to small group size. These mechanisms are collectively known as the Allee Effect and can cause increased extinction risk in very small populations (Allee 1931; Allee *et al.* 1949; Dennis 1989, 2002; Fowler and Baker 1991; Pfister and Bradbury 1996; Courchamp *et al.* 1999; Stephens and Sutherland 1999; Stephens *et al.* 1999; Petersen and Levitan 2001). Rather than reducing reproductive or survival rates at small population sizes, this model explicitly includes the need to find a mate in order to reproduce. Females breed if there is a male within 10 nmi or about half a home range (Rayment et al. 2009). This results in a healthy population growth rate of up to 6% for populations of 100 individuals. An emergent property of the model is that the need to find a mate reduces the reproductive rate at smaller population sizes.

The starting population size was based on the population estimate of 55 individuals in 2011 (Hamner et al. 2012). Biopsy sampling and genetic mark-recapture was used to estimate population size and the government permit for the biopsies did not allow sampling of calves

(Hamner et al. 2012). Approximately 18% of the population would be expected to be ≤ 2 years old. Therefore the model starts with 67 individuals, and is run for two years at the 2012 protection level. The mode of population size after these two years is 60 individuals. Therefore the simulations to compare the three management scenarios start with 60 individuals in 2013 and run for 20 years until 2033. This process was repeated 1000 times for each of the bycatch scenarios.

RESULTS

Estimated population size at the end of 20-years (2013-2033) was compared for three scenarios:

1. Pre-2012 protection level, without the extensions implemented in 2012 and 2013
2. Current protection level, including the 2012 and 2013 extensions
3. Protection level recommended by the IWC

Rapid population decline continues under current management (Fig. 2). There is very little difference between the population trajectories for current protection measures and what would have happened if the two small extensions to the protected area had not been implemented.

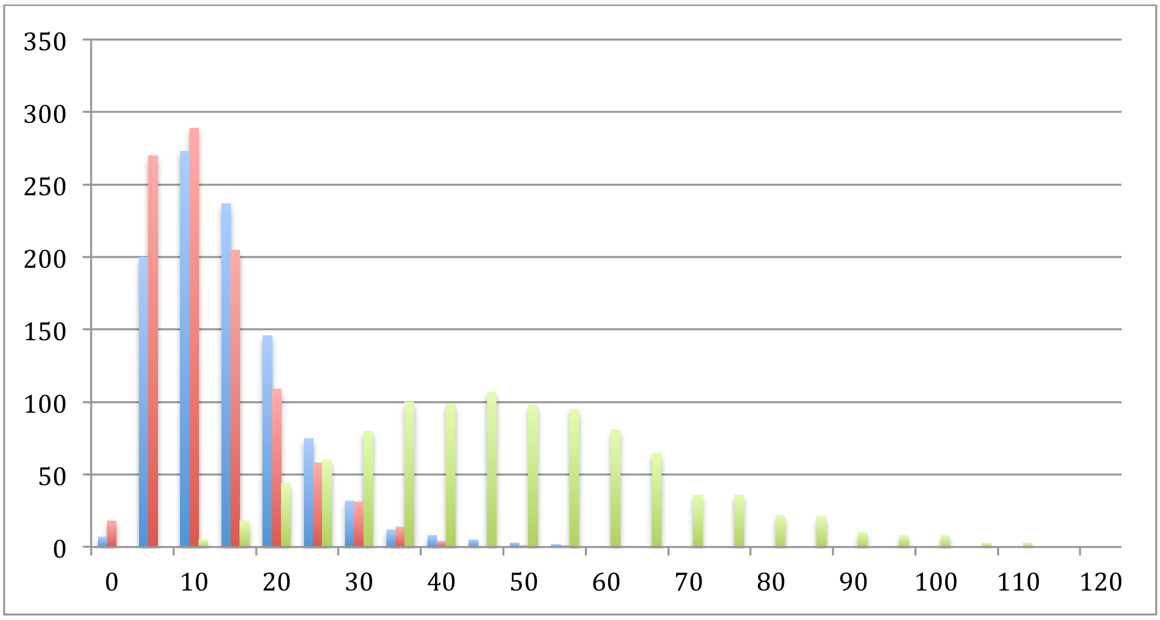

Figure 2. Estimated population size at the end of 20 years under current management (blue), if the two extensions in 2012 and 2013 had not been implemented (red) and under the protection measures recommended by the IWC (green). For each scenario, 1000 simulations were run with a starting population of 60 individuals.

None of the 1000 runs for scenarios 1 and 2 resulted in population growth. The probability of population decline to less than half the starting population size of 60 individuals (Nfinal ≤ 30) was > 95% for scenarios 1 and 2. The probability of the population declining below 10 individuals was on the order of 50% in scenarios 1 and 2. This would mean a population with about 5 females and 2-3 mature females remaining in 2033.

	Scenarios		
% Runs with Nfinal:	2012	2014	IWC
≤ 10	0.58	0.48	0.00
≤ 30	0.98	0.97	0.12
≤ 60 (decline)	1.00	1.00	0.60
> 60 (growth)	0.00	0.00	0.40

Table 1. Proportion of 1000 runs in which final population size was ≤ 10, 30 and 60 individuals, or > 60 at the end of 20 years. Each run started with 60 individuals. The three scenarios compare current management (the 2014 scenario) with the protection measures recommended by the IWC and with a scenario (2012) which does not include the two extensions to the protected area that were implemented in 2012 and 2013.

The probability of population recovery is much higher if the protection measures recommended by the IWC are implemented (Fig. 2 and Table 1). The IWC option results in a 40% probability of population increase. Under current management all 1000 runs resulted in population decline, despite the two extensions to the protection measures in 2012 and 2013. Examination of individual population trajectories indicates that it is critical to ensure the population recovers from its currently very low population size in order to escape the impact of Allee Effects.

DISCUSSION

The IWC Scientific Committee (SC) first discussed NZ dolphin bycatch in 1984, when the Small Cetaceans Sub Committee (SM) 'recommended the continuation of population studies, plus an investigation of the interaction between *C. hectori* and the local fishery.' In 2008, the SC reviewed a quantitative assessment of protected areas for NZ dolphins implemented that year. While these protection measures were a significant step forward in reducing the overlap between fisheries and NZ dolphins, there was still little or no protection for some populations (e.g. west coast and north coast of the South Island). Therefore, the Scientific Committee's 2008 Report 'stresses that additional measures may be required to ensure recovery of the species' (IWC 2009).

In 2012 the SC expressed concern about the low population size of Maui's dolphins, estimated at 55 individuals over one year old (CV 0.15; Hamner et al., 2012). The SC recommended extending the North Island protected area and noted that further population fragmentation could be avoided by providing 'safe 'corridors' between North and South Island populations (Hamner et al., 2012).' In 2013 the SC reiterated its concern, and recommended that 'the highest priority should be given to immediate management actions that will lead to the elimination of bycatch of Maui's dolphins. This includes full closures of any fisheries within the range of Maui's dolphins that are known to pose a risk of bycatch of small cetaceans.' The SC emphasised that the critically endangered status of Maui's dolphin and the inherent uncertainties involved in trying to assess small populations 'require the immediate implementation of precautionary measures. Ensuring full protection of Maui's dolphins in all areas throughout their habitat, together with an ample buffer zone, will minimise the risk of bycatch and maximise the chances of population increase.'

In 2014, the SC emphasized that the current protection measures (described in scenario 2):

'fall significantly short of those previously recommended (IWC 2013; 2014). The Committee reiterates its extreme concern about the continued decline of such a small population as the human-induced death of even one dolphin would increase the extinction risk for this subspecies. It also reiterates that rather than seeking further scientific evidence it is of highest priority to take immediate management actions that will eliminate bycatch of Maui's dolphins. This includes full closures of any fisheries within the range of Maui's dolphins that are known to pose a risk of bycatch of small cetaceans (i.e. set net and trawl fisheries).'

'The Committee notes that the current range of Maui's dolphins comprises the area from Maunganui Bluff in the north to Whanganui in the south, offshore to 20 nautical miles and including harbours.'

The Final Advice Paper from the Ministry to the Minister for Primary Industries in 2013 included a ban on gillnet and trawl fisheries in waters less than 100 m deep from Maunganui Bluff to Whanganui and including harbours (FAP 2013). The Minister rejected this option and indicated that management options using distance from shore as an offshore boundary are preferred to the use of a depth contour, because this was considered be more practical in terms of policing and monitoring. The IWC recommendation takes these practical considerations into account and proposes an offshore boundary of 20 nmi.

So far, there has been no indication that the NZ government intends to implement the IWC recommendation or extend current levels of protection in any other way. Maui's dolphins were discussed at the 2014 Meeting of the (International Whaling) Commission. Thirty-one countries, including the member states of the European Union, USA, Monaco, Switzerland, South Africa, Uruguay and Argentina expressed grave concern over the status of Maui's dolphins and welcomed the work of the Scientific Committee on this subspecies. The New Zealand Commisioner stated that he did not dispute the Scientific Committee's findings, but that current management of Maui's dolphins considers economic and social factors as well as scientific data. Public statements from Crown Law, the Minister and Ministry for Primary Industries and the Minister and Department of Conservation also indicate that the IWC recommendation has been rejected on the basis of 'economic, social and cultural factors' (e.g. Angus and Halley 2014, Crown Law 2015).

Avoiding extinction of Maui's dolphins depends in large measure on ensuring that the population recovers as quickly as possible from the very small current population size. The risk of entering an 'extinction vortex' where reduced population size leads to further reductions in reproduction (and potentially also reduced survival) increases substantially with further declines in population size. This is mainly due to increased difficulties in finding mates in very small populations. Allee Effects caused by other mechanisms (e.g. inbreeding, reduced efficiency in foraging or predator defense, with smaller group size) would also be expected to increase if population size is reduced further.

Current management is predicted to cause further population declines. The small extensions of the protected area in 2012 and 2013 have been ineffective in terms of reducing extinction risk or increasing the probability of achieving a sustainable, let alone recovering population. By contrast, the protection measures recommended by the IWC are much more likely to halt population declines, prevent extinction and achieve recovery from Critically Endangered to Endangered and in the long-term to a non-threatened status.

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