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COMMENT

Modelling the impact of fisheries bycatch on Hector's dolphin: comment on Slooten (2007)

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INTRODUCTION

Slooten (2007) makes management recommendations based on modelling New Zealand Hector's dolphin populations by (1) projecting back from recent abundance surveys to estimate abundance in 1970, and (2) projecting populations forward to 2050 under a range of alternative management scenarios. In this Comment, we question a number of the modelling choices that are relevant to the estimate of population size in 1970, the confidence with which this can be estimated, and the completeness of the model description. We also discuss the credibility of the model outputs in the light of other data that were not included in Slooten's model.

MODEL

Historical bycatch. Although Hector's dolphins are caught as bycatch in set gillnets (setnets), not all setnet fishing effort overlaps with their habitat. Therefore, in estimating historical bycatch, Slooten has excluded effort in some areas. She has excluded effort in her Area 11 (Ministry of Fisheries Statistical Area 018), but offers no information as to what, if any, effort has been excluded in other areas. Inclusion of inappropriate effort will cause overestimation of historical bycatch and hence of carrying capacity, *K*, defined as the population size in 1970. The reader cannot verify that only appropriate effort has been included.

The New Zealand catch and effort database contains detailed setnet fishing effort only after 1982. For the period 1970 to 1982, Slooten (2007, p. 170) estimates annual fishing effort by 'taking the average of the effort reported between 1983 and 1985' and so assumes that effort is constant at the level of the 1983 to 1985 mean. The database does contain setnet catch data by port of landing before 1983. A better approach would be to infer setnet effort from the reported catch of relevant species or from published but incomplete estimates of effort. The total New Zealand catch histories (Fig. 1) for 2 of the major setnet target species that occur in dolphins' depth range, rig *Mustelus lenticulatus* and school shark *Galeorhinus galeus*, show significant increases during the period 1970 to 1982, and only approach the average catch in 1983 to 1985 at the end of the period. These known catch histories are inconsistent with the assumption that setnet fishing effort from 1970 to 1982 averaged the levels reported in 1983 to 1985.

Massey & Francis (1989) note that commercial setnet fishing on the east coast of the South Island expanded significantly in the summers of 1976/1977 and 1977/1978. This is consistent with the increase in catches of rig and school shark seen in Fig. 1. Taylor (1992) suggests a major expansion in the setnet fishery occurred in the early 1980s. 1983 to 1985 probably represents a *maximum* for setnet effort, because it was the period immediately prior to the introduction of the ITQ (Individual Transferable Quota) management system. Catches of both rig and school shark fell immediately after the introduction of the ITQ management system (Ministry of Fisheries 2007), which put Total Allowable Catch constraints on landings. The overestimate of effort during 1970 to 1982 results in overestimated bycatches that inflate the model estimate of *K*.

Invariant bycatch rate. Slooten's (2007, p. 170) model incorporates a 'dolphin entanglement rate,' *M*, that is spatially and temporally invariant, based on estimates made by Baird & Bradford (2000). Their esti-

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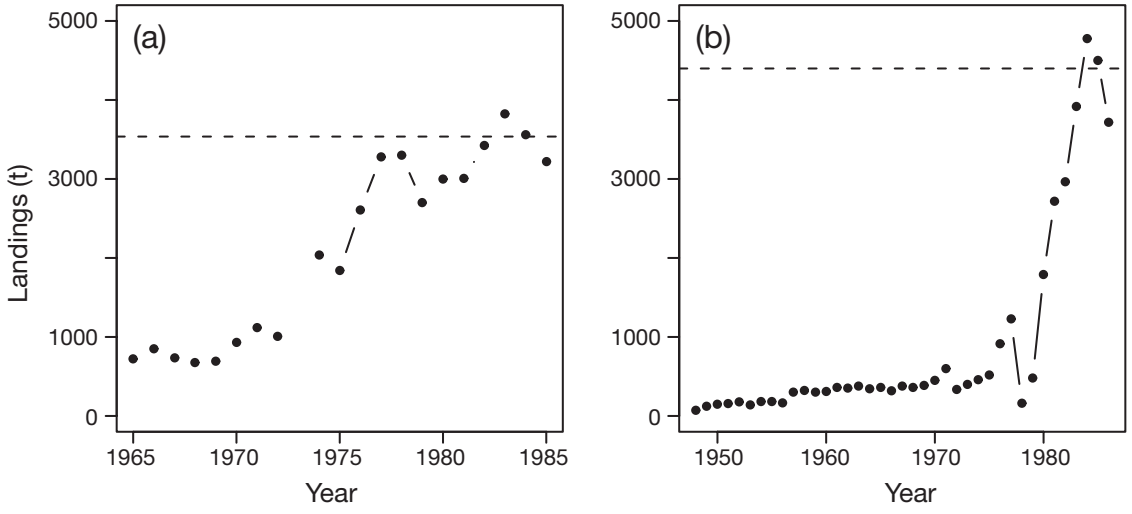

Fig. 1. *Mustelus lenticulatus* and *Galeorhinus galeus*. Annual landings of (a) rig and (b) school shark in New Zealand. Data from Ministry of Fisheries (2007). Horizontal dashed lines give the mean annual catch for 1983 to 1985

mates of mean bycatch rates for the adjacent Statistical Areas 020 and 022 in 1997/1998 differ by a factor of more than 5, but Slooten aggregates these areas (her Model Area 12) and ignores this spatial variation. Baird & Bradford (2000) estimated the mean number of dolphins captured per net setting event, ignoring the net's length. Slooten has converted this rate to captures per m of net per km^2. The data used to convert captures per set to captures m^{-1} km^{-2} are not given, nor are the resulting estimates of *M*. Her estimates therefore cannot be confirmed. Two of the 8 observed captured dolphins were released alive, but Slooten, without comment, treats these as though they were dead. Her procedure for back-calculation of population size in 1970 incorporates no uncertainty in *M*, even though Baird & Bradford's (2000) estimates of bycatch rates in Areas 020 and 022 had coefficients of variation (CVs) of 71 and 43%, respectively.

OUTPUTS

Bycatch estimates. Slooten (2007) does not provide her model estimates of fisheries bycatch, only the resulting population estimates. However, her model suggests a decline in population from 29316 in 1970 to 7873 in 2007, which represents a net loss of 21443 dolphins in 37 yr. This implies an average net loss of almost 580 dolphins per annum. Actual bycatch estimates from the model would be higher due to the compensatory population growth implicit in the Schaefer surplus production model. For example, assuming λ_{max} at Slooten's lower bound of 1.018, a population decline to half carrying capacity results in a surplus production increase from zero to 132 ind. These additional dolphins would also be killed during the decline.

In contrast to these inferred bycatch rates are data on known dolphin mortalities. Anonymous (2007) gives a maximum of 125 reported Hector's dolphin mortalities and 11 Maui's dolphin (North Island Hector's dolphin) mortalities for any *decade* since October 1969. While reported and beachcast mortalities are clearly an underestimate of actual mortalities, the difference between a *decadal* maximum of 136 reported mortalities from all causes, and an average *annual* model estimate of more than 580 from fisheries mortality alone, does not seem credible.

Although Slooten (2007) does not report her population estimates at the scale of the 16 areas in her model, the population change for the South Island east coast population implies an annual net loss of 233 dolphins as a result of fisheries mortality. The adjacent Statistical Areas 020 and 022 represent the core of the dolphin's range on the South Island east coast (Dawson et al. 2004, their Table 4) and are also the areas with the greatest level of setnet effort which poses a potential threat to Hector's dolphins (Anonymous 2007), so this area would be expected to produce the majority of setnet mortalities. Prior to the establishment of the Banks Peninsula Marine Mammal Sanctuary, the highest reported bycatch estimate (anecdotal) for this area was 'at least 230' dolphins over the period 1984 to 1988 (Dawson 1991). Although this is presented as a lower bound, it is nonetheless a small fraction of the bycatch implied by the model. Baird & Bradford (2000) include dolphins released alive and estimate 18 captures in 1997/1998 in Statistical Areas 020 and 022.

Population trajectory. Slooten's (2007) modelling implies a steeply declining population trajectory with a

loss of 73% of the total 1970 population by 2007. Population declines are estimated for all 4 regions over this period, ranging from 49% for the south coast of the South Island to 93% for the North Island west coast. These results are not supported by other information.

Pichler (2002) examined mitochondrial DNA from Hector's dolphins around New Zealand and concluded that while the North Island west coast and South Island east coast populations showed genetic evidence of a decline, there was no evidence of a decline in the west coast South Island population. Slooten's (2007) model estimates a decline of 67% for the latter population.

The series of Hector's dolphin surveys around New Zealand conducted from 1998 to 2004, and used as the basis of Slooten's modelling, resulted in a total species estimate of just under 7400 ind. This was a considerably higher estimate than the 3408 ind. estimated in a strip transect survey in 1984/1985 (Dawson & Slooten 1988). The main difference between these 2 sets of estimates was the much greater abundance for the west coast of the South Island in the 2000 survey. Slooten et al. (2004) concluded that the earlier strip transect survey had probably underestimated dolphin numbers due to conditions on the exposed west coast. However, for other areas of the South Island, Dawson et al. (2004) concluded that the 1997 to 2000 estimates of abundance 'were not significantly different from those estimated in the 1984–85 strip transect survey.' Dawson et al. (2000) consider it unlikely that the 1984/1985 estimate for the Motunau to Timaru area (part of the South Island east coast population) was biased low. The 2004 estimate of abundance of the west coast North Island population of 111 dolphins (95% CI 48 to 252; Slooten et al. 2006) suggests a modest decline from the estimate of 134 in 1985 (Dawson & Slooten 1988). Thus, while Slooten's (2007) modelling suggests a large decline in the population over the period 1970 to 2007, survey estimates for all areas (other than the west coast South Island where the earlier estimate may have been biased low) suggest stable populations between 1984/1985 and 1998 to 2004.

Cawthorn (1988) used incidental sighting data from 1970 to 1984 to 'speculate on the possible population size' of Hector's dolphin in New Zealand waters. His estimate of a maximum of 5000 to 6000 is consistent with a rather flat population trajectory between the early 1980s and the surveys of 1998 to 2004.

Slooten's (2007) interpretation of the population trajectory is not consistent with the estimates reported. She reports a model estimate of 7873 ind. in 2007 (i.e. almost 500 greater than the combined 1998 to 2004 survey estimates) yet claims that this represents a 'continuing decline' under current management.

Uncertainty. There is a high level of uncertainty in any population estimates based on the available data for Hector's dolphin. Slooten (2007) includes uncertainty in maximum population growth rates and (apparently) in recent population size. We feel that substantial further uncertainty has been omitted. A single bycatch mortality rate per unit of setnet effort, M, applied throughout the whole of the modelled period and to all areas of New Zealand, is estimated from few observations in 1 area in 1 yr. Even if this were well estimated, the amount of setnet effort to which the dolphins have been vulnerable is uncertain, especially prior to 1983.

Although Slooten's focus is on management rather than population trajectory estimation, we feel that the former cannot be properly addressed without proper acknowledgment of uncertainty in the latter.

CONCLUSION

Although we support the use of population models for informing management, we find substantial deficiencies in Slooten's (2007) modelling. These include the overestimation of historical bycatch, the failure to acknowledge the high level of uncertainty in the results, the inconsistency between results and other available information, and the lack of a description of methods sufficient to allow confirmation of results.

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Conflict of interest statement. David Middleton is a Senior Scientist with the New Zealand Seafood Industry Council (SeaFIC). SeaFIC's science group works to ensure that the seafood industry can rely upon high quality and credible science advice, and actively participates in Ministry of Fisheries, Department of Conservation, and other technical and planning processes. Paul Starr is a former Chief Scientist of, and a continuing science contractor to, SeaFIC. He was responsible for the 1997/1998 observer programme which provided the bycatch estimate used by Slooten (2007), and has recently worked as a subcontractor to the National Institute of Water and Atmospheric Research (NIWA) on a Ministry of Fisheries contract to assess risk to Hector's dolphin populations. Dave Gilbert has recently resigned from the role of Group Manager of NIWA's Fisheries Modelling Group, but is still a collaborator in NIWA's contract to assess risk to Hector's dolphin populations. All authors have participated in Ministry of Fisheries and Department of Conservation working groups, including meetings with Dr. Slooten.

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