Appendix 1 – Hector's and Māui Dolphin Threat Management Plan Review, Risk Assessment Workshop, 9-13 July 2018. Panel Recommendations.

Panel Comments and Recommendations

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Introduction

This document provides the comments and recommendations of the Expert Panel that participated in the Hector's and Māui Dolphin Threat Management Plan Risk Assessment Workshop in Wellington, 9-13 July 2018. The workshop discussed and reviewed a wide range of material presented by those directly working on the plan, and also benefited from the active participation of other scientists who have studied this species and of individuals representing a number of interested organisations.

Although the Terms of Reference for the workshop made clear that risk management discussions were out of scope, they also made clear that the Threat Management Plan (TMP) process was meant to serve the Ministers by not only enabling government to ensure the "long-term viability" of the Māui and Hector's dolphin populations, but also by "leading the recovery process." The workshop's purpose was to identify, analyse and evaluate threats to both subspecies and to identify those threats that pose the greatest risk to achieving management objectives, whatever they might turn out to be.

Summary of Panel views of the approach and methods used in the risk assessment

Aspects that the modelling (as presented at the workshop) does well:

- Habitat mapping is very useful.
- Determining the spatial overlap between commercial fishing and the dolphins' occurrence provides a sound basis for focusing observer effort and for informing other monitoring elements.
- The modelling provides at least a qualitative list of other threats that deserve further investigation.
- The spatial modeling of threats should aid in focusing research efforts according to which areas may warrant threat-specific research and/or management.

Aspects that could be improved:

- Reference to conservation status of the species, subspecies, and populations of Hector's dolphins is needed. Especially given the *spatial* emphasis of the analyses, explicit attention should be given to issues of maintaining, and where necessary recovering, the full distribution of the species (we recognize that this implies addressing the difficult question of establishing a historical baseline of some sort).
- Ministers may request advice on how to manage risks to small, vulnerable populations of Hector's dolphins and thereby maintain genetic diversity, but the modelling (as presented) would not provide a basis for such advice. At a minimum, it would be helpful for the report to include a table that identifies and characterizes small populations for which the model might not identify risks well.
- Assuming that beach-cast carcasses are representative (or even a rough approximation) of the actual proportions of causes of death is problematic. Inclusion of a table or tables of necropsy results and related information (e.g. carcass locations, spatial overlap with dolphin distribution and river outlets) may help, but concern about inferences made from this will remain.
- Recreational and illegal fishing (as sources of bycatch) need to be accounted for more clearly and robustly.
- Although considerable attention is given to uncertainty, it will be important to give greater attention to degrees of certainty, e.g. explaining strengths and weaknesses of inferences, showing where results come from extrapolation or interpolation rather than empirical data.
- Further validation of inputs (e.g. ground-truth monitoring to identify when the model isn't predicting well) is needed. One example would be seeing how well the model fits when back-casting from current abundance data and fisheries observer data to past abundance estimates (at least for some areas and with coverage in all areas constrained to be the same).

Recommendations

Overall Approach

1. The SEFRA approach succeeds in separating out the precautionary aspects of population management from the uncertainty in the available information and also in capturing and representing some of that uncertainty (though see points below on recreational and potential illegal setnetting). The panel is impressed by the representation of commercial fisheries uncertainty, but has concerns about the utility and practicality of setting targets based on the science that will then be modified by managers to determine levels of risk tolerance. In particular, this strategy makes determination of the level of precaution a matter for negotiation rather than an inbuilt feature as is the case for an approach like PBR where N_{MIN} is set as the 20th percentile of a log-normal distribution and specified recovery factors are applied. It is hard to see how the two approaches – one clearly separating science and conservation, the other building in specific precautionary buffers – could be formally tested against each other, and this choice will always be a matter of judgement and opinion.

2. The Risk Atlas is a good interface. There will always be possibilities for adding bells and whistles, but the current functionality seems adequate. The only extension for which we can currently foresee a need is an ability to incorporate a set of surfaces, representing uncertain spatial distributions, as an alternative to the current single surface with uncertainties.

3. The application of the SEFRA methodology to Hector's and Maui dolphins efficiently extracts information from the data it uses, but also highlights the limitations of this data and the urgency of a continuing program of collecting data (i.e. monitoring). The structure of the models is appropriate to the data, with difficulties arising mainly where extrapolation is required into areas and conditions with little or no data. In particular, the use of the habitat model for extrapolation between areas may be problematic for these depleted populations. The sparsity and patchiness of the data also suggest that there is unlikely to be much benefit in formal testing of model fits. Cross-validating, by fitting models to different parts of the data and estimating everywhere from each, may give more useful results.

4. The approach attempts to be very clear ('transparent') about the choices that have been made along the way. However, subjective decisions seem to have crept into the selection of the final models. For example, several habitat models were plausible and some fit the dolphin density distributions in some areas better than others. Given time, habitat models could be weighted by their AIC or some other rationale for weighting could be conceived. A way

also needs to be found to deal with sightings and habitat distributions that don't match. See Appendix 1 for draft decision rules that may help.

5. The presentation of uncertainty is clear for many aspects, but it is particularly important to ensure that all sources of uncertainty have been captured and represented appropriately and that known or potential sources of impact that haven't been included (such as recreational and illegal setnet fishing) are explicitly acknowledged. Spatial uncertainty in the distribution maps is an issue that may need some further consideration.

6. There appears to be quite a lot of previously collected data that hasn't been used in this process. For example, several previous abundance estimates exist for at least some areas where effort was comparable, and these could have been used to examine predicted versus observed numbers in different years. Published data on movements could be used to constrain the size of strata or the reallocation of dolphins according to the habitat model to areas beyond expected movements. While it will not be possible to explicitly include all previously collected data, even for model testing, it would be useful to have, at least, a catalogue of all the data with explanations of what couldn't be used and why.

7. While the approach is designed to use sparse data efficiently, it remains particularly vulnerable to biases in such data. For issues such as toxoplasmosis, where many assumptions are necessary to construct the spatial distributions required and to interpret the available data, a simple narrative approach, listing what is actually known, may be more appropriate.

8. We have reservations about applying the excellent spatial modelling framework, which includes both dolphin densities and assumed levels of exposure to identified risk factors, as a way to rank the relative importance of those risk factors. Attempting to account for all causes of death – whether 'natural' or human-caused – in a credible quantitative analysis that fully incorporates uncertainty is an ambitious, and in our considered view unrealistic, goal. Attaining such data has not been possible for any marine mammal species and is likely to be an unattainable goal without allocation of a large amount of resources. Although we consider the work presented at the workshop innovative and thorough, and therefore an interesting contribution, we urge the team to avoid 'overselling' the results in the final report.

9. The TMP should provide information that will help managers make decisions without recourse to having the plan revised for different management objectives. Therefore, covering commonly agreed principles of conservation biology for maintaining healthy populations seems prudent: preserve genetic diversity, avoid fragmentation. These principles would put special emphasis on several key populations: 1) Māui dolphins (North Island genetic diversity), 2) Te Waewae Bay to Toetoes/Porpoise Bays (South Island genetic diversity),

and 3) the north end of the South Island, including Golden Bay (connectivity between SI east and west coasts and potentially with the North Island). Each of these three 'populations' are at low numbers and deserve priority for monitoring and thereby could inform the model as to whether observed population growth or adult survival match what would be expected from model predictions.

10. It is important that the results of the process are accessible to non-scientists. Alongside the technical information, which is essential, simplified outputs should be provided, such as probability of population increase, or most likely, best, and worst plausible outcome for a particular area and overall. As choices are necessary to interpret even 'most likely', 'plausible', 'best case', and 'worst case', it may be worth attempting to agree these with the various interest groups *before* the numerical results are available.

Population Status

11. The TMP needs to include a firm basis for determining the current status of dolphin populations in relation to their historical abundance and distribution so that 'recovery' can be defined and worked towards. This means that even if the spatial modelling approach to risk assessment as developed by the risk assessment contract team is based only on currently observed environmental conditions and the dolphins' current demographic and ecological characteristics, there is a responsibility to ensure that at least some of the available information on previous dolphin occurrence is presented in the TMP. As a start, a qualitative review could be included somewhere in the document based on the short summary of published, albeit largely anecdotal, historical information provided to the Workshop by Gemma McGrath ("Early abundance and distribution of Hector's/Māui dolphins").

12. For depleted populations, managers may want to minimize the amount of time over which those populations remain at very low abundance and therefore are at greater risk of being extirpated. Identifying which populations are at high risk will help managers, should they have this preference. The current model does not give managers this information (status relative to historical numbers). It would be useful to provide a summary of status, by population, for future risk assessments. We recommend that, at a minimum, the present effort include an attempt to identify demographically independent populations of Hector's dolphins (see Appendix 1) that are at numbers typically considered to be so low (below the low hundreds) that they are at high risk. For these populations it would be helpful to project the consequences of management options over the near future (say 20 years).

13. A population analysis should be included in the TMP if not also (or instead) as part of the risk assessment report. At a minimum, the population analysis should include a population projection for the near future that accounts for known anthropogenic mortality compared with a projection with no anthropogenic mortality. For the *māui* subspecies, this could be along the lines of that already produced by Cooke et al. (2018). For the *hectori* subspecies, this will be more complicated and require a different approach, ideally one that is population-specific rather than for the subspecies as a whole. Ideally, a back-projection would allow readers to know current population status relative to abundance several generations in the past. Such model-projected historical abundances could be compared to some earlier abundance estimates in specific areas.

14. Given the apparently low numbers of individuals and the relative demographic isolation of certain local populations of Hector's dolphins, consideration should be given to conducting future genetic/photo-id mark-recapture studies modelled after those carried out on Māui dolphins. The rationale for doing this is that the desired recovery and 'long-term viability' of these populations may require management interventions similar to those being applied to Māui dolphins. See point 6 for at least 3 such populations that may require further population structure and monitoring research.

15. The Population Sustainability Threshold (PST) is directly related to r_{max} (the maximum growth rate biologically possible for the species). The value of r_{max} used by the modelling team relies on a method developed by Dillingham that uses values for many other mammals and relies on certain life history trade-offs. For data-poor species, the produced value yields an expected value given size and age at first reproduction. For this case, such an approach *could* be misleading as another outcome from analysis of multiple long-lived mammals is that growth rate changes with abundance primarily as a function of changing reproductive parameters (birth interval or age at first reproduction). Hector's dolphins are very small and live in cold waters, so giving birth to a large calf is energetically costly. The minimum interbirth interval is 2 years. It is plausible that under ideal conditions, the observed age at first reproduction could be 6 given that it is about 7 years in the population that surrounds Banks Peninsula, which is at relatively high numbers. To test the sensitivity of the model output to r_{max} we recommend using these values together with the highest observed adult survival rate. It is likely that this will result in an r_{max} of roughly 3.5% rather than the currently used value of 5.5%. This difference of 2% could seriously affect interpretation of the consequences of anthropogenic mortality. At a minimum, a sensitivity analysis using an alternative r_{max} would help readers understand the importance of this choice to the TMP results.

Distribution and Abundance

16. Using habitat models as the sole means of producing dolphin density maps for a given abundance may not faithfully capture abundances of separate populations. Habitat models use current distribution to predict where dolphins 'should' be. However, this species has experienced depletion to the point of local extirpation (or nearly so) in Hawkes Bay on the North Island and it is not implausible that the South Island has been differentially depleted because of likely unequal historical setnetting that has been the result of differential access of fishermen to different areas. Differential depletion is also expected because Hector's dolphins show high site fidelity based on ample data from both photo-id and genetic studies, and because protection measures have been implemented in differing amounts at different times and in different areas. An alternate model should be considered that uses abundance estimates for areas deemed to contain demographically independent populations. Within these populations, dolphins would be distributed according to the spatial habitat model (see Appendix 1).

    We recommend that this alternate, spatially constrained model be presented as a comparison to the model that distributes dolphins based solely on the habitat model. It is likely that there is even more population structure than the strata suggested in Appendix 1, so the model proposed there should have a caveat that it is exploratory in nature and does not represent a final population structure but would be a large step in that direction. It should also be noted that differences between the models may not be large given the nature of the current model that produces a snap-shot of apparent risks today and does not project into the past or the future. It will be particularly interesting to compare the two approaches for areas where multiple abundance estimates over time are available (notably Banks Peninsula), to see how the models perform relative to those estimates both with and without the spatial abundance constraints.

    If maintaining population structure is important to achieve management goals, advances in eDNA could allow rapid increases in the data available for use in genetic population structure analyses without the need to biopsy animals in the small populations around the north and south ends of the South Island (though biopsies will still be less expensive to analyse and have not been shown to be a health concern for the targeted individuals).

17. For a population model that projects populations (see point 10) and considers population structure, movement between populations can be important. To investigate whether low levels of animal movement could result in source/sink dynamics that could significantly alter model conclusions, a model that allowed a 1%/year movement between neighboring populations along the east coast and the west coast of the South Island is recommended. Further discussion is needed on potential connectivity across the north end of

the South Island but given the strong genetic differences at the south end, the populations there should not be connected to either the east or west coast.

18. Consider whether turbidity affects detectability in aerial surveys, the implications of any such effects, and how to account for them. (Deanna Clement indicated that turbidity definitely affected detectability.) Note that detection probability differences could contribute to both underestimation of abundance in turbid areas and overestimation in clear waters. Comparisons of circle-back data from areas of differing turbidity would be an immediate source of data to investigate this issue. There is some potential that the differing abundance estimates in Cloudy Bay (which ironically, given the name, is indicated as having relatively lower turbidity than the high-turbidity areas near Banks Peninsula) are positively biased if dolphins in Cloudy Bay had a longer detection period (i.e. were 'available' for detection longer) than dolphins in more 'typical' (i.e. more turbid) areas.

19. Aerial survey data from the University of Otago are available from DOC and an effort should be made to find and use those data to improve the distribution and relative density predictions from spatial habitat modelling – as a supplement to or check on the data from the 2010-2015 aerial surveys currently used in the model.

Modelling

20. Investigations should be carried out on how well the habitat usage maps represent low-density areas. This will only be a problem if the patterns change between areas. Weighting observations is one possible alternative to the informal model selection currently used.

21. There is spatial uncertainty in the GAM models of distribution. This can be estimated by drawing from each model's parameter covariance matrix. A few draws from this may be enough to show whether there is a large enough effect to be concerned about. If there is, it may be necessary to carry a set of replicates, rather than a single surface, into the RiskAtlas.

22. The shape of the lower end of the adult survival prior is effectively unconstrained other than by zero. The input for the current adult survival rate is a very important input to the model. Data on adult survival rate are available for only two areas: West Coast North Island (*maui* subspecies) and Banks Peninsula. The upper limits to adult survival are constrained by biology, but low survival is unconstrained. For most of the geographical distribution of Hector's dolphin there are no data to inform the model, so whatever adult survival distribution is put in is what you will get out. Since Banks has legal protection from fishing (and thus presumably would be expected to have a lower bycatch risk) and has had such protection for longer

than anywhere in New Zealand, using the Banks adult survival rate as a prior could result in a positive bias in the survival estimate. Thus, in areas that are data-free in terms of demographic parameters (particularly small or vulnerable areas like Te Waewae Bay and Golden Bay), the model has the potential of giving a picture that all is well, when there are no data that would give 'feedback' to indicate that the prior doesn't match the empirical data (because there are no empirical data for those areas). For such cases that lack independent demographic data *and* are small *and* are clearly so genetically different that they have no recent connection to nearby populations for the purposes of rescue, independent data are needed to inform the model. Such validation data could include data on trends in abundance or estimates of adult survival.

One way to clearly communicate data inputs and limitations would be to include in the report a table with the agreed (and named and/or numbered) strata for the spatial modelling exercise as rows and a number of columns including at least: abundance, CV, trend data available (Y/N), adult survival data available (Y/N), setnet observer data for this population (Y/N)… or even better, % observed effort for this population, trawler observer data for this population (Y/N), setnets banned within 4nmi (Y/N) and if Y then date of regulation in parentheses.

23. It was agreed during the workshop that the modelling team would implement a way to account for bycatch events in which multiple dolphins (2 to 5) were caught.

Bycatch

24. More attention should be given by the modelling team to the way observer coverage has been used to infer bycatch mortality rates. We are particularly concerned about making it transparent to readers that many areas have little to no observer coverage and even in those that do, observer coverage is low and often from some time ago. Perhaps a map or table could communicate level of coverage best. Or a decision could be made about criteria (perhaps based on a combination of SE and CV – CV works well for large values, but a large CV around a small estimate will probably be less interesting than the equivalent SE) that indicate areas where the data are sufficiently uncertain that the point estimates risk confusing casual readers, or relevant areas could be delineated with a warning about over-interpreting fine detail. .

25. If a Minister is being pressured to increase or otherwise modify observer coverage, the model as presently constructed should be able to provide advice on this by using the 'risk coverage' concept, for example by considering areas with little to no observer coverage to be 'high-risk' or by employing the 'observer coverage simulator tool' mentioned by Ben Sharp (which is planned

under a new contract that has not yet been tendered). The effectiveness of this approach should be tested by carrying out a separate simulation exercise using artificial data.

26. Available data from the observer program should be mined for information on how Hector's dolphins behave near trawl nets and observers on trawlers should be explicitly asked to record such information as part of their regular duties (several workshop participants confirmed that they had observed dolphins approaching and feeding near trawls so some information is definitely available for scrutiny). This information might be useful to assess whether depredation or scavenging increases the vulnerability of Hector's dolphins to bycatch in trawls. Since depredation is a learned behavior, there may be differential risk in different populations.

27. Although the subject of differential bycatch risk according to mesh size of gillnets was raised and briefly discussed during the workshop, we recommend that this question be pursued further by the modelling team and that adjustments to inferred bycatch rates for the various fleet components be made if warranted.

28. The issues of recreational and illegal setnet fishing were discussed at some length during the workshop and participants suggested several ways of accounting for this mortality, which is not currently considered in the model. For example, David Higgins reported that a harvest survey of recreational fishing had been conducted; the data from that survey should be checked. Also, it was suggested that there may be an opportunity for including questions on recreational gillnetting as part of the exit survey for the current National Panel Survey. Fisheries New Zealand is said to have a database of offences by region (reports from 'fish cops'), and investigation of that database and other sources of compliance/enforcement information could provide the basis for at least a qualitative evaluation of scale, locations etc. Finally, it was pointed out that the extensive effort at gillnet/ghost-net removal in Mexico (part of the vaquita conservation program; see item 4 in report at http://www.iucn-csg.org/wp-content/uploads/2010/03/CIRVA-8-Report-Final.pdf) showed that subsurface gillnets are detectable on fish-finding sonar. A targeted effort should be considered to detect nets in areas where such activity (whether legal recreational netting or illegal netting) is known to have occurred in the recent past, or where there is reason to suspect that it still occurs.

    We recommend that a layer be generated in your model that accounts for mortality caused by types of fishing not represented in the observer data set, i.e. the mortality caused by recreational and illegal fishing. This could be based on access points and any other information (anecdotal or otherwise) that can be extracted from previous research or from knowledgeable informants. It will then be important to solicit or search for independent data on mortality due to recreational or illegal fishing that can be used to validate model predictions.

Sound

29. The sound modelling was impressive but a lot of computing power seems to be going into areas and frequencies that are likely not relevant for Hector's dolphins (though see below regarding uncertainty surrounding hearing abilities). Can the bounds (physical and noise frequency) and grid sizes (in time, space, and frequency) be 'traded off' to gain more spatial precision and generate results for more receiver locations? Maps with contours (or even bounds) of noise levels in the coastal habitat might be useful for discussions of rerouting traffic or otherwise limiting vessel activity.

    It was noted during Craig McPherson's presentation that several sources of underwater sound that are particularly relevant to high-frequency cetaceans like Hector's dolphins were not included in the JASCO modeling. If the results of this modeling are going to be used to help characterize and quantify noise disturbance as a threat, then the sound from small vessels (that are not normally equipped with AIS), echosounders, sonars and pile driving should either be incorporated into the modelling (which apparently would be prohibitively expensive) or, at a minimum, be described as a shortcoming of depending on McPherson's modelling study alone to account for the true scale of potential noise disturbance in the area.

    In later discussion it was noted that the auditory characteristics of Hector's dolphins have not been characterized and that although these dolphins must hear at least within the same high frequency range in which they project sound, they may be able to hear in lower frequencies as has been shown for harbor porpoises. Captive Commerson's dolphins may provide an opportunity to quantify lower frequency hearing capacity and thereby improve evaluation of frequencies that likely heard by Hector's dolphins. This would still leave unresolved the questions of how particular levels of exposure are likely to affect individuals and populations.

30. Continue and if feasible expand acoustic monitoring with archival recorders in areas where Māui dolphins are 'normally' seen or are likely to be seen (based on habitat suitability, public sightings, historical information etc.). Data obtained from such monitoring would help to ground-truth acoustic propagation models and more importantly, add high-frequency components such as echosounders and sonars that are currently not modelled.

31. The initial efforts using C-PODs and sound traps to improve understanding of how far offshore Māui dolphins range were productive, and additional effort of this kind is encouraged. Passive acoustic monitoring should be further

explored as a means of (i) ground-truthing the results of habitat suitability modelling, especially in areas of currently low dolphin density, (ii) learning more about dolphin occurrence in harbours, for example, where there is little or no coverage by aerial surveys or other sources, (iii) obtaining better information on nighttime distribution and acoustic behaviour, and (iv) learning more about offshore-inshore movement patterns.

In this context, the process used to develop acoustic monitoring for vaquitas would be useful to consider. That process convened an expert panel consisting of scientists knowledgeable about the animals, the acoustic instruments, deployment and retrieval methods etc. It took about two years to develop a deployment/retrieval method that worked in vaquita habitat and no doubt a similar effort would be required to develop an effective monitoring scheme for Māui dolphins. The benefit would be having in-hand thousands of days of data on how the dolphins use their habitat, and this would not only improve spatial habitat models but also make it possible to obtain data on nighttime habitat usage, which is currently unaccounted for. It is also very important that the monitoring be annual for critically endangered populations where a 5-year gap in knowledge can prove fatal (i.e. lead to extirpation or at least near-extirpation). The catastrophic decline in vaquitas was detected within 2 years of the start of the sharp downward trend and management actions were initiated immediately.

Necropsy data & Toxoplasmosis

32. The necropsy data on toxoplasmosis is both striking and concerning. It certainly needs to be presented and emphasized, along with similar information from other species (e.g. sea otters in California, Hawaiian monk seals). However, we are not convinced that it is appropriate for the toxoplasmosis necropsy data to receive the full modelling treatment: the uncertainties and potential biases in these data are too large. If the effects of the disease are as large as they appear, and the deaths are additional to other causes, we would expect the populations of Hector's dolphins to be in rapid free-fall towards extinction. Hopefully, many of the observed deaths were of animals that were already compromised in some other way or ways and therefore were exceptionally susceptible. Nonetheless, we strongly recommend further investigation of this issue.

33. Considering the 28 necropsies (between 2007-2011) for which cause of death was determined (of which 6 are characterized as 'open' and 4 are attributed to bycatch) to be a representative profile of total mortality for the species seems like a questionable decision. There is no reason to believe that beach-cast carcasses (and particularly such a small sample of these) are representative of deaths of all kinds throughout the dolphin population. Defining how and to what extent this sample of deaths could be biased is a

nearly intractable problem, and although we understand the underlying reasons for developing the model around that sample as the 'best available quantitative data' on cause of death for Hector's dolphins, we are concerned that the results from the model could be seriously misleading. For this reason, we recommend that you 'back off' from forcing the model to produce conclusions which are supportable only when a series of questionable assumptions are made and which even then, are highly uncertain. Although as indicated during the workshop, we encourage you to present the necropsy findings in your report and to discuss their potential strengths and weaknesses (and biases) in detail, we also recommend that you avoid overselling the model results in terms of assigning relative proportions to the various causes of death.

It should be feasible to retain the many excellent insights gained from the modelling and input development concerning spatial relationships and overlap between the known or potential causes of mortality, both direct and indirect, and the distribution and density of dolphins, without necessarily reaching firm conclusions on the relative significance of different causes of death. The work as presented to the workshop makes clear the importance of vigorously pursuing more information on all aspects of the toxoplasmosis problem. The data that have been assembled and the approaches that have been proposed by the modelling team thus far should be useful for identifying likely 'hotspots' of exposure and for devising 'countermeasures' to reduce the risk to some extent.

34. An additional category of 'unobserved cause of death' should be included in analyses of the necropsy data. This is necessary because only a small number and proportion of carcasses are recovered, meaning that even fairly frequent causes of death could be missed. (A simplified example of the problem: If there were two causes of death that each accounted for half of the mortality but only one carcass was found, then only one cause would be observed. If two carcasses were found, other things being equal, there would still be a 50% chance that they would both have the same cause of death. As the number of carcasses recovered increases, the chances of missing major causes of mortality will decrease, but even with 30 carcasses with identified causes of death, from a set of 10 equally common causes, there is a 30% chance of not observing one cause and another 5% chance of missing two.) The aim of this work would be to get an idea of the plausibility that a major cause of death would have been missed in the available data. Repeating the calculations with multiple unobserved categories would provide a sense check on the results of this analysis; splitting the unobserved category should not change the results (since it adds no extra information).

Climate change

35. The main workshop did not cover climate change or environmental change in a systematic way, though Jim Roberts raised these issues informally. It would be useful to include in the final TMP a more developed treatment of his ideas concerning the potential impacts of climate change and other major environmental changes. If a quantitative treatment is not possible given the timeline and other work recommended in this report, a qualitative discussion with descriptions of next steps should be added.

Miscellaneous

36. The matter of estimating dolphin ages from teeth should be revisited. Some of the differences shown in the presentation on this topic appear systematic, more like scatter round a curve rather than a straight line. It would be worth re-examining these data to see if that would change any of the conclusions being drawn from them.

37. The issue of applying satellite-linked radio tag technology was raised but not discussed during the workshop. Such technology has been applied successfully to studies of franciscana dolphins in Argentina, which are also very small animals, occur in turbid estuaries, and are subject to frequent bycatch in gillnets (Wells et al. 2013). The idea of tagging Hector's dolphins is bound to be controversial but should not be ruled out. Instead, a risk vs reward analysis should be carried out in which the risks to the dolphins are weighed against the potential for resolving critical uncertainties.

References

Cooke, J.G., Steele, D., Hamner, R., Constantine, R. and Baker, C.S. 2018. Population estimates and projections of Māui dolphin (*Cephalorhynchus hectori maui*) based on genotype capture-recapture, with implication for management of mortality risk. Unpublished paper submitted to IWC Scientific Committee, document SC/67B/ASI/05.

Jaramillo-Legorreta, A., Cardenas-Hinojosa, G., Nieto-Garcia, E., Rojas-Bracho, L. et al. 2016. Passive acoustic monitoring of the decline of Mexico's critically endangered vaquita. Conservation Biology https://doi.org/10.1111/cobi.12789

Wells, R.S., Bordino, P. and Douglas, D.C. 2013. Patterns of social association in the franciscana, *Pontoporia blainvillei*. Marine Mammal Science 29(4):E520-E528.

Appendix 1

Decision rules for dealing with differences between density/abundance estimates obtained from sighting surveys and estimates generated by habitat modelling:

1. Apportion abundance into sub-areas (set using what's known from photo ID and genetics) as follows –

    - South Island East Coast – Some 'stepping stone' dispersal between 5 units (e.g. 1% a year)

    - South Island South Coast – Treat as a separate population with the caveat that it may consist of multiple populations (Te Waewae Bay separate from Toetoes Bay/Porpoise Bay).

    - South Island West Coast – Again, some "stepping stone" dispersal between 3 units.

    - South Island North Coast – Needs more discussion (Barbara doesn't know enough about this area and consultation is likely needed with others who have direct experience in the area).

    - Note: Specific boundaries can be worked up further.

2. For each area –

    - In areas of low density with few to no sightings, use an alternate abundance/density estimate. For example, use the mark-recapture estimate for the Dunedin stratum A Bayesian approach that uses variance from the full survey to estimate the probability of sighting no dolphins in the strata with zero sightings but where dolphins are known to be present from the public sightings data may be appropriate. It would yield insight on the probability distribution for abundance estimation in the Dunedin stratum where an alternative estimate is available. The Bayesian aerial survey estimate should be as high as the mark-recapture estimate as that estimate could be negatively biased but is unlikely to be positively biased.
    - In other areas, use the aerial survey estimate unless an alternative estimate covers the same area and is more precise.
    - For Cloudy Bay, use the aerial survey estimate as a base case and the two genetic mark-recapture estimates as alternatives, taking probability distributions from both and drawing equally from each.

Within each area, the habitat model is used for finer-scaled distribution of density.