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13th May 2021

Dear Marine Mammal Commission,

We greatly appreciate your interest in our research, and the letter (dated 5th April 2021) with your follow-up questions related to our presentation on 23rd March 2021 of the Barataria Bay dolphin population model. Your questions regarding the projected effects of the proposed Mid-Barataria Sediment Diversion (MBSD) project on recovery of the Barataria Bay Estuarine System (BBES) dolphin stock are important to consider when balancing the benefits and costs of the proposed MBSD project. The expected effects on the stock over time and space are also important to consider for ensuring sufficient monitoring of dolphin population health status and resources for stranding response, and to develop potential mitigation measures. To summarize briefly, you asked us to incorporate the modeled annual survival rates estimated by Dr. Garrison into the refined population model discussed by Dr. Schwacke to determine 1) the projected effects of the project on dolphin recovery over time, and 2) how the project could delay recovery of the BBES Stock.

We have conducted the requested analysis and provide a description of methods and findings in an attached report. In brief, our analysis indicates that the project (based on the Applicant's Preferred Alternative [APA]) will not only prevent the recovery of the BBES Stock, but it will result in the functional extinction of dolphins in the West, Central, and Southeast strata of the stock area. The only dolphins remaining in the basin would live adjacent to the barrier islands, and even this group will become severely reduced over the 50-year planning horizon of the MBSD project.

Yours faithfully,

Len Thomas and coauthors Tiago Marques, Cormac Booth, Ryan Takeshita and Lori Schwacke

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5 April 2021

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Dear Drs. Schwacke, Srinivasan, and Garrison:

The Marine Mammal Commission would like to thank you for your participation in the "Effects of Low Salinity Exposure on Bottlenose Dolphins" webinar on 23 March 2021, and the presentations made by Drs. Schwacke and Garrison on the status and health of the Barataria Bay (BB) stock of common bottlenose dolphins and the potential effects of the Mid-Barataria Sediment Diversion (MBSD) on that dolphin stock.

The BB stock of bottlenose dolphins experienced significant mortality from the 2010 Deepwater Horizon (DWH) oil spill. There was a 51 percent mean proportional decrease of the BB bottlenose dolphin stock as a result of acute DWH oil spill-related exposure (Schwacke et al. 2017). A large percentage of the pre-spill cohort continues to exhibit poor health, most notably from persistent lung disease, impaired stress response, and other ailments. The refined population model discussed by Dr. Schwacke on the webinar showed that the BB population is currently near its lowest level, ten years after the spill. The population's recovery is still uncertain, but the projected time to recovery estimated by the refined model is 32 years. The effects of various restoration efforts (whether positive or negative), as well as a changing climate, were not included in the refined model but Dr. Schwacke noted those effects could have a significant impact on population recovery trajectories.

Dr. Garrison presented a model showing the projected impacts of the MBSD on the BB dolphins, as outlined in more detail in Garrison et al. 2020. The model indicated a 36 percent reduction in the mean annual survival rate of dolphins due to projected freshwater inputs. That projection was based in part on dose-response functions generated by an expert elicitation of the effects of low salinity water exposure on bottlenose dolphins (Cormac and Thomas 2021), which were also presented as part of the 23 March 2021 webinar.

Would it be possible to incorporate the modeled mean annual survival rates estimated by Dr. Garrison into the refined population model discussed by Dr. Schwacke to determine the projected effects of the MBSD project on dolphin recovery over time, and how the MBSD project could delay recovery of the BB dolphin population?

The Commission is very interested to know whether you would be able to conduct these additional analyses, particularly before the end of the public comment period on the MBSD draft environmental impact statement (4 May 2021).

Sincerely,

Peter O. Thomas, Ph.D.,
Executive Director

Cc: Drs. Cormac Booth and Len Thomas, SMRU Consulting, Inc.

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Predicted population consequences of low salinity associated with the proposed Mid-Barataria Sediment Diversion project on bottlenose dolphins in the Barataria Bay Estuarine System Stock

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13th May 2021

Summary

1. The proposed Mid-Barataria Sediment Diversion (MBSD) project will result in decreased levels of salinity in Barataria Bay, Louisiana. This decreased salinity has been predicted by the National Oceanographic and Atmospheric Administration (NOAA) to cause increased mortality of bottlenose dolphins in the Barataria Bay Estuarine System (BBES) Stock.

2. We used an existing model for the population dynamics of this stock to predict the population consequences of the increased mortality. We compared population projections under two scenarios (described in the Draft Environmental Impact Statement for the proposed project), "Applicants Preferred Alternative" (APA) and "No Action Alternative" (NAA), using the same four geographic regions ("strata") as NOAA and assuming no movement of animals among strata.

3. The model predicts an immediate and severe population-level decline under the APA. In the first year of operation under the APA (2027), median predicted excess mortality under the APA is 585 dolphins (95% confidence interval [CI] 131-1459), leading to a median stock decline of 23% (95% CI 3-55). By contrast, under the NAA the stock is predicted to increase by 3% (95% CI 1-5) − the increase is because the stock is estimated to still be in recovery from the *Deepwater Horizon* oil spill. Therefore, after one year of operation, the stock is predicted to be 25% smaller (95% CI 6-56) under the APA than under the NAA.

4. After 10 years of operation, the parts of the stock in the Central and West strata are predicted to be functionally extinct (probability of < 30 animals remaining is 1 in the Central stratum and 0.99 in the West stratum). The part in the Southeast stratum, while not extinct, is predicted to be 82% lower (95% CI 44-96) under the APA than under the NAA. The Island stratum is less severely affected with a median predicted decline of 38% (95% CI 9-84).

5. After the planned 50 years of operation, dolphins in three out of the four strata are predicted to be functionally extinct under the APA, with the remaining Island stratum being severely reduced relative to the NAA (median predicted population size of Island stratum is 85% lower [95% CI 28-99] under the APA than under the NAA). Overall, by the year 2076, the median predicted stock size across all of Barataria Bay under the APA is 143 dolphins (95% CI 11-706) compared to 3363 (95% CI 2831-4289) under the NAA. In other words, the stock is predicted to be 96% smaller (95% CI 80-100) under the APA than then NAA.

Introduction

The Barataria Bay Estuarine System (BBES) Stock of bottlenose dolphins was heavily impacted by the *Deepwater Horizon* (DWH) oil spill. A population model (Schwacke et al. 2017) was developed to quantify the impact, and this model has recently been updated as part of a Gulf of Mexico Research Institute consortium project (CARMMHA) to collect additional information and refine the impact quantification (Schwacke et al. in preparation).

One proposed habitat restoration effort is the proposed Mid-Barataria Sediment Diversion (MBSD) project, which proposes to intermittently release water from the Mississippi River into the upper Barataria Basin. This will result in decreased levels of salinity in the basin that, in turn, will cause mortality of dolphins in the BBES Stock. The potential extent of this mortality was examined in a recent report by the National Oceanographic and Atmospheric Administration (NOAA; Garrison et al. 2020). That report gave predictions of annual survival rates in four geographic regions ("strata") within the Barataria Basin (Island, Southeast, Central and West) under two scenarios presented in the Draft Environmental Impact Statement for the proposed project: the "Applicants Preferred Alternative", where the MBSD is constructed and begins operation in 2027, and the "No Action Alternative", where the MBSD is not constructed.

In this report, we integrate the annual survival of dolphins in each of the four strata from the two scenarios of Garrison et al. (2020) into the population model developed under the CARMMHA project, and use this to predict the consequences of the proposed MBSD project for the dolphin stock.

Methods

Impact on survival from NOAA analysis

We obtained from NOAA 1,000 replicate predictions of estimated annual survival under APA and NAA scenarios in each of the four strata, derived from the model of Garrison et al. (2020). The replicate predictions represent the range of scientific uncertainty on possible impacts, accounting for factors such as uncertainty on the salinity field for a given set of hydrographic conditions, uncertainty on animal movement and hence exposure, and uncertainty on the effect of low salinity on dolphin survival (see Garrison et al. 2020 for details). Note that all predictions are based on a single assumed annual hydrograph, that for 1970 (Garrison et al. 2020), and so do not account for uncertainty in future hydrographic conditions (see Discussion).

For each replicate prediction and stratum, we calculated the percentage difference in survival between the APA and the NAA as follows:

$$\% \text{ difference in survival} = \frac{\text{survival under APA - survival under NAA}}{\text{survival under NAA}} \times 100$$

The resulting distribution of percentage difference in survival in each stratum is shown in Figure 1, with associated summary statistics in Table 1. For the Island stratum, the median prediction is of a 2% decline in survival under the APA relative to the NAA, although in 10% of replicates the predicted survival decline is greater than 20%. For the Southeast stratum, the median prediction is of a 14% decline in survival with 40% of replicates predicting a survival decline of greater than 20%. Note, however, that 24% of replicates in this stratum predict an increase in survival under APA relative to the NAA. For the Central and West strata there is a large predicted decline in survival under almost all replicates.

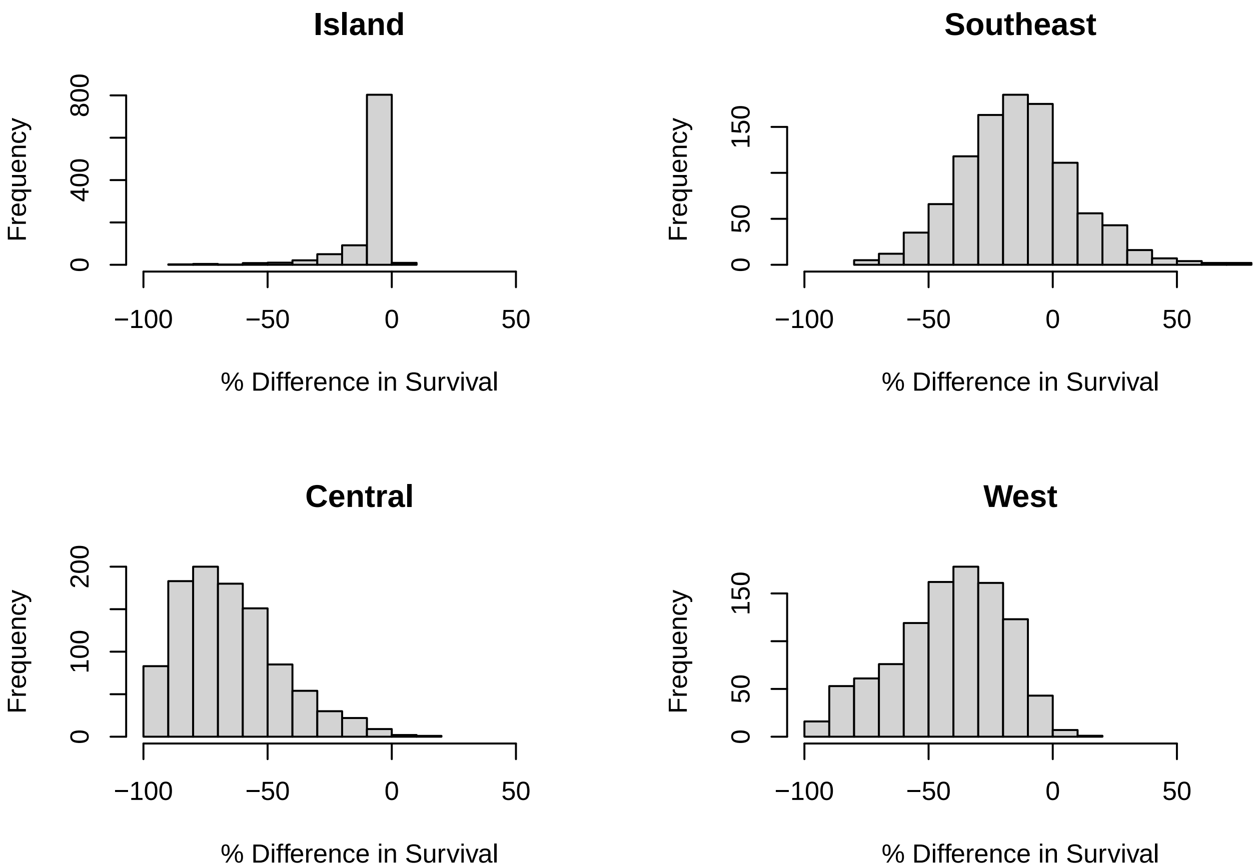

Figure 1: Predicted percentage difference in dolphin annual survival under the Applicant Preferred Alternative (APA) compared with the No Action Alternative (NAA). One thousand predicted survival rates were provided by NOAA and were derived from the model of Garrison et al. (2020).

Table 1: Summary statistics on predicted percentage difference in dolphin annual survival under the APA relative to the NAA. First column is median predicted percentage difference, second is percentage of replicates that predict a decline in survival of 20% or more, third is percentage of replicates that predict an increase in survival.

Stratum	median % diff	% (diff < -20%)	% (diff > 0)
Island	-2	10	1
Southeast	-14	40	24
Central	-68	97	0
West	-39	83	1

Population consequences

The population model of Schwacke et al. (in prep.) gives estimates of the population trajectory of BBES dolphins from 2010 onwards, accounting for the estimated effect of the DWH oil spill. We used this model as the basis to predict the estimated effect of the proposed MBSD project (APA) on the dolphin population. Like the APA survival predictions from Garrison et al. (2020), the population model accounts for scientific uncertainty in predictions by allowing multiple replicates to be drawn. We therefore based our predictions on 1,000 replicate samples.

For each sample, we partitioned the BBES dolphin population into the same four strata as Garrison et al. (2020), using estimates of the proportion of the total population with home range centers in each of the four strata. These estimates come from a spatial capture recapture analysis (Glennie et al. in prep.) that forms part of the inputs to the Schwacke et al. model. For the purposes of this analysis, we assumed that each stratum is demographically independent – i.e., that dolphins in the BBES stock do not move from one stratum to another. For each stratum, we ran the Schwacke et al. model for 75 years (2010-2076), under two scenarios. In the first scenario, representing the APA, for each year after the proposed MBSD project begins in 2027 we adjusted the survival values from the Schwacke et al. model using a random draw from the 1,000 values of percentage difference in survival for that stratum. In the second scenario, representing the NAA, we ran the Schwacke et al. model without modification.

We calculated the following metrics to summarize outcomes from the population model:

- In the first year of operation of the MBSD (i.e., 2027-2028)
  - Excess mortality: the total number of dolphins that are expected to die this year under the APA minus the number that are expected to die in the same year under the NAA.
  - Change in population size under the APA and under the NAA.
  - Percentage difference in population size in 2028 between APA and NAA.
- After 10 years of operation of the MBSD (i.e., in 2037)
  - Probability of functional extinction, where functional extinction is defined as < 30 animals.
  - Percentage difference in population size in 2037 between the APA and NAA.
- In the final year of operation the MBSD operations planning horizon (i.e., 2076)
  - Probability of funtional extinction.
  - Population size under the APA and under the NAA.

In each case, we report the median value from the 1,000 replicate simulations, together with the lowest 2.5th and highest 97.5th percentile – these latter values represent a 95% confidence interval on the prediction.

Results

We first present graphical representations and a qualitative description of the results, before presenting the summary metrics described in the Methods.

Figure 2 summarizes the population trajectories over all 1,000 realizations under APA (red) and NAA (black) scenarios. The populations follow the same trajectory under both scenarios up until 2027, when proposed MBSD operations start. During this period (2010-2027) the populations experience the negative effect of the DWH oil spill and, starting around 2020, begin to recover. After 2027 under the NAA, the populations continue to recover and reach a steady state long before the end of the simulation time period. Under the APA the median prediction for the Island stratum is of a steady decline, while the other strata experience rapid declines to extinction. The prediction at stock level, i.e., summing across strata, is shown in Figure 3. Under the APA, the stock is predicted to decline precipitously at first and then more gradually, reaching very low levels relative to the NAA by the end of the simulation time period.

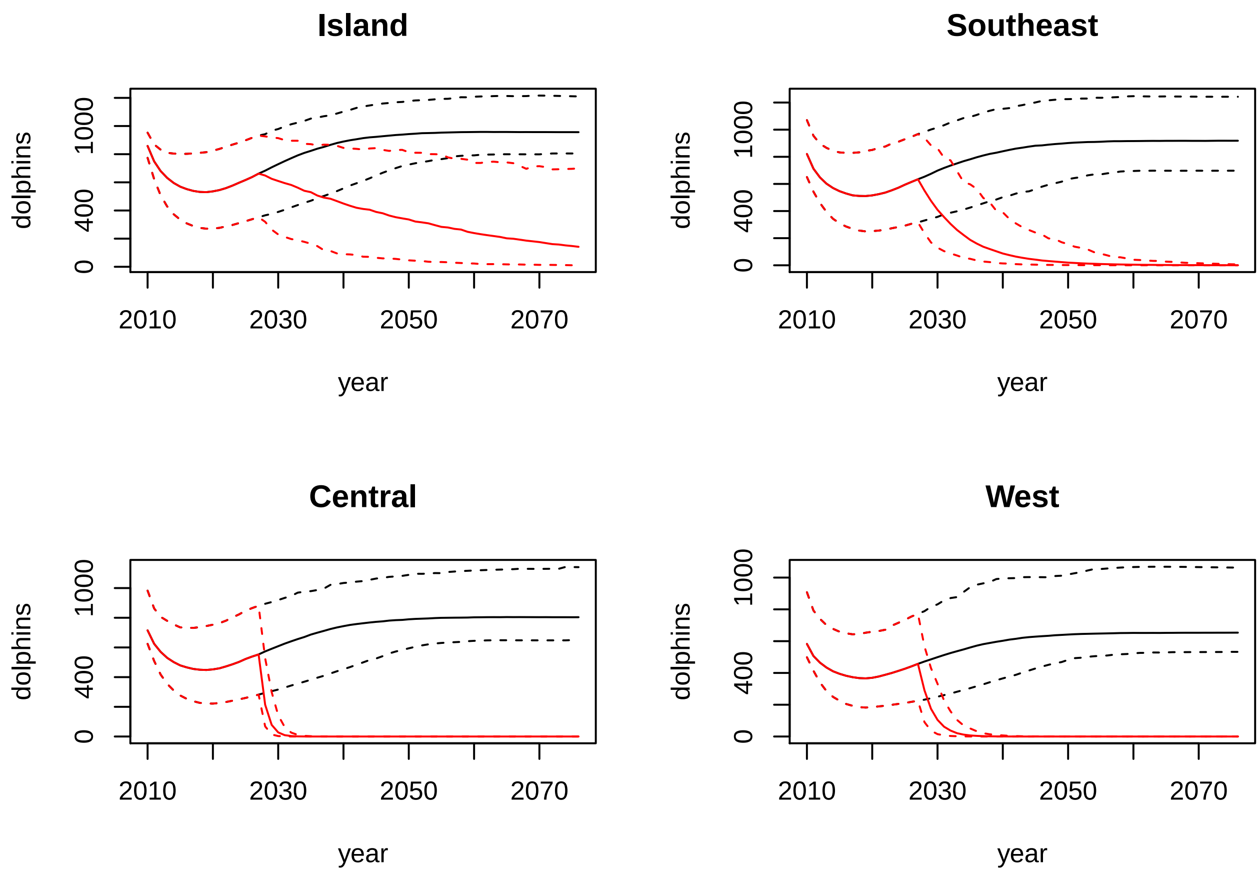

Figure 2: Summary of predicted population trajectories by stratum under the Applicant Preferred Alternative (red) and No Action Alternative (black) scenarios. Solid line shows median; dashed lines show 95% confidence limits.

The summaries given in Figures 2 and 3 are computed from 1,000 random realizations of the model. Figure 4 shows 10 example realizations. The part of the stock in the Island stratum experiences occasional large population decreases associated with years where there is a large decline in survival under the APA; in most years, however, there is little or no decline. After 50 years of operation, all realizations have experienced an overall decline and none are at the level of the corresponding NAA. The part of the stock in the Southeast stratum experiences frequent stronger declines, but also occasional increases associated with survival increase under the APA. Nevertheless, after 50 years of operation, all realizations are at or close to zero. The parts of the stock in the Central and West strata experience rapid declines towards zero in all realizations.

Quantitative summaries of the results are given in Tables 2-6[1]. Table 2 shows the predicted mortalities in the first year of the proposed MBSD operation (2027) under APA, NAA and the difference between the

[1]Note that in all these tables, the median shown in the “Total” row is calculated by first aggregating the strata and then calculating the median. This is not the same as simply summing the stratum medians. The same is true for the confidence limits.

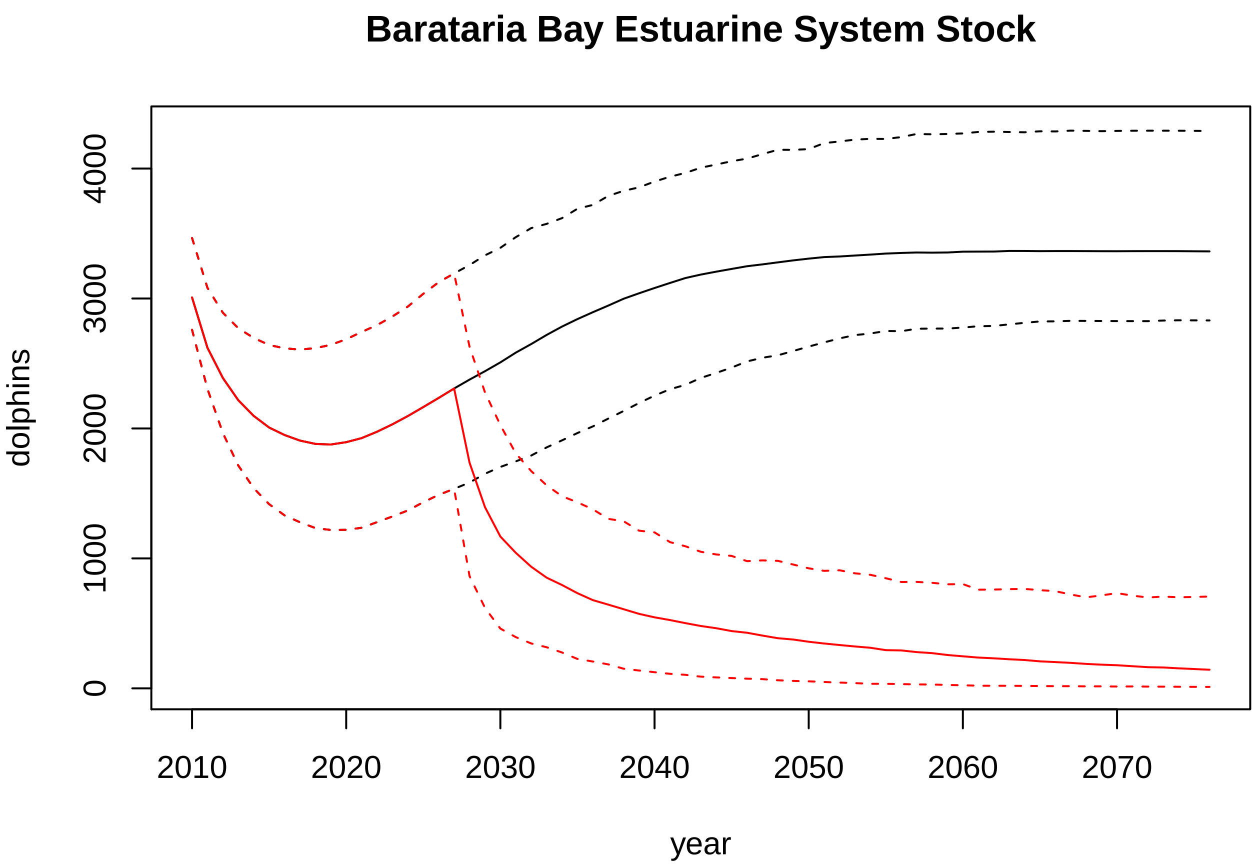

Figure 3: Summary of predicted stock trajectory under the Applicant Preferred Alternative (red) and No Action Alternative (black) scenarios. Solid line shows median; dashed lines show 95% confidence limits.

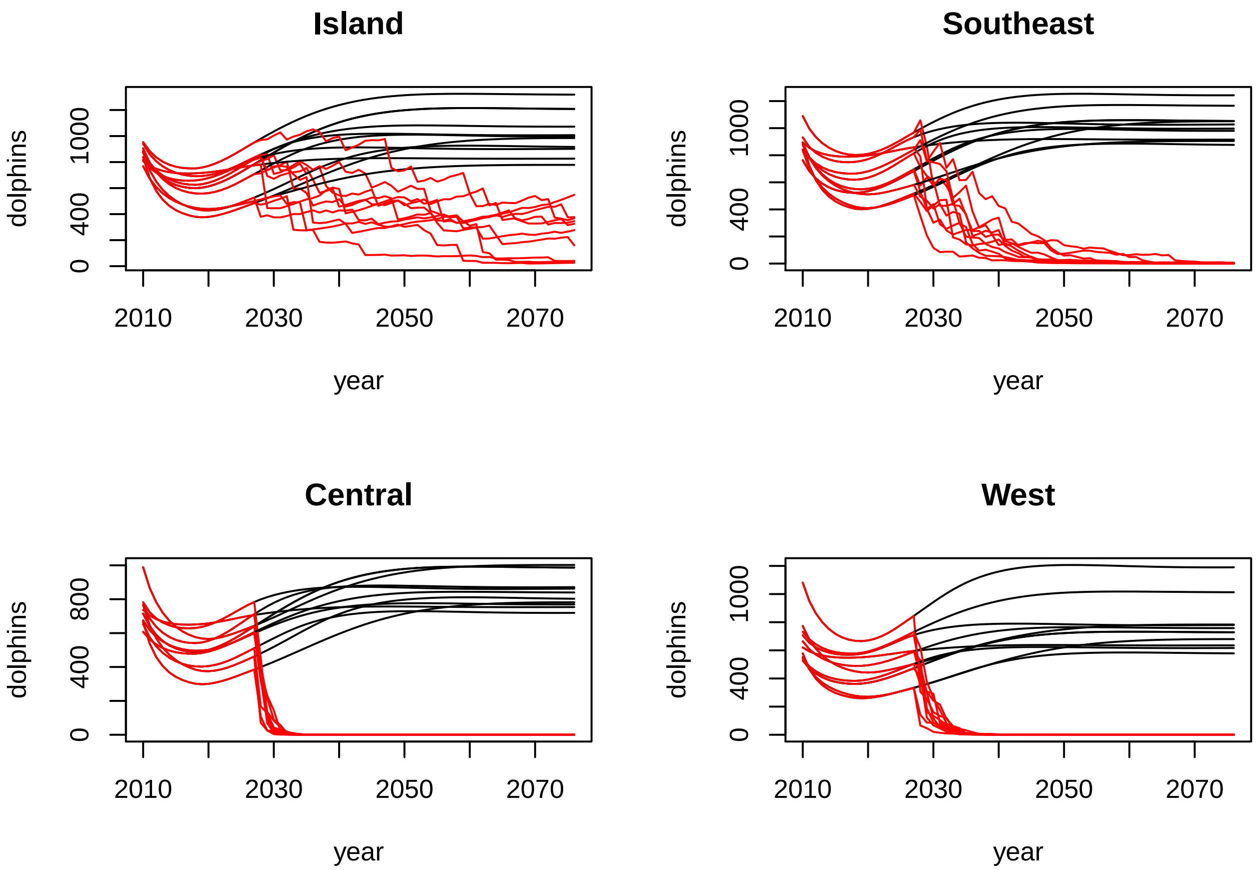

Figure 4: Ten example realizations of the population simulation under the Applicant Preferred Alternative (red) and No Action Alternative (black) scenarios.

two, which represents the predicted excess mortalities under the APA scenario. In this first year of MBSD operation, the median predicted excess mortality under the APA is 585 dolphins with 95% CI 131-1459. This excess mortality represents a median of 26% of the stock (95% CI 6-58) killed by the MBSD in its first year of operation.

Table 2: Predicted dolphin mortality in 2027 under APA and NAA scenarios. Last column shows excess mortality – i.e., mortality under APA minus mortality under NAA. Values are medians from the model simulations, with 95% confidence intervals in brackets.

Stratum	APA mortality	NAA mortality	excess mortality (APA-NAA)
Island	59 (26 — 261)	44 (23 — 64)	12 (0 — 217)
Southeast	111 (0 — 424)	42 (22 — 66)	69 (-50 — 367)
Central	364 (120 — 715)	37 (19 — 59)	326 (92 — 656)
West	186 (53 — 461)	30 (15 — 52)	154 (31 — 420)
Total	740 (26 — 261)	156 (23 — 64)	585 (131 — 1459)

Estimated stock size in the 2027, before operation of the proposed MBSD, was 2307 animals (95% CI 1535-3193). Estimated stock sizes in 2028 under the APA and NAA are shown in Table 3. Under the APA, the stock is predicted to decline by 23% (95% CI 3-55) due to mortalities caused by the MBSD operation. By contrast, under the NAA the stock is predicted to increase by 3% (95% CI 1-5) – the increase is because the stock is estimated be still in recovery from the DWH oil spill. Therefore, by the end of the first year of MBSD operations, the stock is predicted to be 25% smaller (95% CI 6-56) under the APA than under the NAA (Table 3).

Table 3: Predicted number of dolphins in 2028 (after 1 year of operation of the MBSD) by stratum and overall under APA and NAA scenarios, and percentage difference between scenarios. Values are medians with 95% confidence intervals in brackets.

Stratum	APA dolphins	NAA dolphins	% difference
Island	648 (320 — 926)	683 (366 — 942)	-2 (-31 — 0)
Southeast	551 (237 — 939)	653 (330 — 983)	-12 (-49 — 7)
Central	214 (68 — 528)	573 (294 — 894)	-61 (-87 — -17)
West	291 (90 — 567)	472 (232 — 789)	-35 (-79 — -7)
Total	1736 (864 — 2629)	2376 (1584 — 3258)	-25 (-56 — -6)

Tables 4 and 5 show the predicted population size in 2038 and 2076 respectively (i.e., after 10 years of operation of the MBSD and at the end of the 50 year planning horizon) under APA and NAA, as well as the difference between the two scenarios.

Table 4: Predicted number of dolphins in 2038 (after 10 years of operation of the MBSD) by stratum and overall under APA and NAA scenarios, and percentage difference between scenarios. Values are medians with 95% confidence intervals in brackets.

Stratum	APA dolphins	NAA dolphins	% difference
Island	491 (118 — 868)	852 (503 — 1070)	-38 (-84 — -9)
Southeast	137 (28 — 497)	810 (457 — 1126)	-82 (-96 — -44)
Central	0 (0 — 0)	712 (409 — 997)	-100 (-100 — -100)
West	2 (0 — 21)	581 (328 — 964)	-100 (-100 — -97)
Total	644 (184 — 1304)	2946 (2076 — 3790)	-78 (-93 — -59)

Table 5: Predicted number of dolphins in 2076 (at the end of the planning horizon for the MBSD) by stratum and overall under APA and NAA scenarios, and percentage difference between scenarios. Values are medians with 95% confidence intervals in brackets.

Stratum	APA dolphins	NAA dolphins	% difference
Island	142 (11 — 700)	956 (805 — 1210)	-85 (-99 — -28)
Southeast	0 (0 — 7)	918 (698 — 1243)	-100 (-100 — -99)
Central	0 (0 — 0)	804 (650 — 1141)	-100 (-100 — -100)
West	0 (0 — 0)	654 (533 — 1063)	-100 (-100 — -100)
Total	143 (11 — 706)	3363 (2831 — 4289)	-96 (-100 — -80)

Table 6 shows the predicted probability of functional extinction (i.e., proportion of simulation runs where the number of dolphins is less than 30) in each stratum in 2038 and 2076.

Table 6: Predicted probability of functional extinction (i.e., fewer than 30 dolphins remaining) by stratum in 2038 (after 10 years of operation of the MBSD under APA) and 2076 (at the end of the planning horizon for the MBSD)

Stratum	p(extinct) in 2038	p(extinct) in 2076
Island	0.00	0.1
Southeast	0.03	1.0
Central	1.00	1.0
West	0.99	1.0

Discussion

Under the assumptions of this model, there is predicted to be a severe decline in stock size caused by the MBSD under the APA scenario. The stock is predicted to become functionally extinct in three out of four strata and severely reduced in the fourth. The declines are more severe than those estimated to have been caused by the DWH oil spill and will take place just as the stock is starting to recover from the oil spill. While the stock is estimated to recover fully from the DWH oil spill under the NAA scenario, this will not happen under the APA scenario.

We set a limit for "functional extinction" of 30 animals. To our knowledge there is no agreed threshold, and other reasonable values could have been used to indicate the point at which there are so few animals they no longer form a functioning part of the ecosystem. Regardless of the value used, the above findings would be qualitatively the same

These results were generated by combining two separate analyses: the survival predictions from Garrison et al. (2020) and the population model of Schwacke et al. (in prep., updating Schwacke et al. 2017). These use some overlapping information – the photo-ID surveys undertaken in Barataria Bay from 2010-2019. Hence it would be possible, with more modelling effort, to integrate the two more closely by building components of the Garrison et al. model into the population model. However, this is not expected to make a qualitative difference to the population predictions.

The analysis undertaken here sampled values at random each year from the predicted survival effects under the APA and NAA generated by Garrison et al. (2020). This is equivalent to assuming the factors driving the uncertainty in predicted survival effects vary each year. While this is correct for some sources of uncertainty (e.g., uncertainty in salinity field given hydrography; animal movement and hence exposure), it is not fully correct for others (e.g., uncertainty on dolphin survival response given exposure). Ideally, the different components of uncertainty in the Garrison et al. model would be separated and then we could sample as appropriate at the annual level or just once per population projection. This reduction in annual variability would be expected to produce a somewhat more positive population projection, particularly in the Island stratum. However, one very important source of annual variability was neglected in these simulations: annual change in hydrography. The predictions we used from Garrison et al. model were based on a single annual hydrograph, from 1970 (cycle0, Garrison et al. 2020), when in reality hydrography is expected to vary substantially between years. This variability will mean that there are years of worse survival than predicted by Garrison et al. and years of better survival. The overall effect of this on the dolphin population will be to produce a more negative trajectory, because years of poor survival produce large decreases in population size, but in years of good survival the population can only increase by a small amount as it is constrained by the birth rate. The population can decline by 25% in a bad year but it cannot increase by 25% in a good year. Given this, we anticipate that addressing all of the issues related to uncertainty discussed in this paragraph will lead overall to more negative population predictions.

Another factor that makes our projections optimistic is that the population dynamics model is deterministic – it does not account for the random nature of births and deaths, and also allows non-integer population counts. Incorporating demographic stochasticity in the model, and restricting population sizes to be whole numbers will produce more negative predictions, although the difference will not be significant until the populations become small.

The analysis also assumed that the four strata are demographically independent. If dolphins move away from the three more affected strata into the Island stratum in response to low salinity then the stock-level effects may be lower; on the other hand, if dolphins disperse between strata without regard to salinity changes then more animals will move into the strongly-affected strata from the less-affected Island stratum and the stock-level effects may be greater. Genetic analyses have supported spatial structure within the Barataria Basin population, and have identified genetically distinct dolphin groups in the Western, East/Central, and Island portions of the basin (Rosel et al. 2017, Speakman et al. in prep.). Tracking of Barataria Basin dolphin movement patterns via satellite-linked tags has shown multi-year site fidelity to small home ranges (Wells et al. 2017), and have not shown changes in movement that are coincident with fluctuating salinity (Takeshita et al. submitted).

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