Appendix F: NMFS Entanglement Risk

This appendix contains the analysis conducted by NOAA's Climate, Ecosystem, and Fisheries Initiative that evaluates the impact the Risk Assessment and Mitigation Program (RAMP) on blue and humpback whale entanglement risk.

Blue and humpback whale entanglement risk in California's Dungeness crab fishery following the RAMP's implementation

This report is a contribution of NOAA's Climate, Ecosystems, and Fisheries Initiative. Prepared in September 2024 for California's Department of Fish and Wildlife by:
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Background and summary

The Risk Assessment and Mitigation Program (RAMP) came into effect during the 2019-2020 Dungeness crab fishing season. The purpose of this report is to quantify the impact of RAMP mitigation efforts on blue and humpback whale entanglement risk in California's Dungeness crab fishery. CDFW requested a comparison of the implementation period (2019-23) and two baseline periods: long baseline (2014-19), and short baseline (2017-19). Whale distributions were derived from species distribution models, and fishing effort was derived from Vessel Monitoring System (VMS) data informed by landings receipts. Post-RAMP estimated risk was calculated by overlapping modeled whale distributions from the implementation period with modeled fishing effort from the implementation period (Fig. 2). Status quo estimated risk was calculated by overlapping modeled whale distributions from the implementation period with average fishing effort from the long and short baseline periods (including and excluding the large marine heatwave, respectively, Fig. 2). Blue whale estimated risk decreased by 42% and 19% relative to the long and short baseline periods, respectively. Humpback whale estimated risk decreased by 26% relative to the long baseline period, and increased by 2% relative to the short baseline period (Table 1). Most of the estimated risk reduction for both species occurs in November and from April-July, with estimated risk in the implementation period increasing in December and January relative to the long baseline period. While these changes may be the result of RAMP mitigation efforts, they may also reflect unmeasured socio-economic changes within the fishery between the baseline and implementation periods (see Caveats).

Glossary

- **Short baseline:** the 2017-18 and 2018-19 fishing seasons. The short baseline excludes the large marine heatwave.

- **Long baseline:** the 2014-15, 2015-16, 2016-17, 2017-18, and 2018-19 fishing seasons. The long baseline includes the large marine heatwave.
- **Implementation period:** the 2019-20, 2020-21, 2021-22, and 2022-23 fishing seasons. The 2023-24 fishing season was not included due to the unavailability of fishing effort data as of writing.
- **Fishing effort:** fishing activity inferred from crab fishing vessels equipped with VMS transponders linked to port level fish tickets to identify target species, measured as number of VMS telemetry pings per grid cell.
- **Whale distribution:** Species distribution model-derived distributions of blue and humpback whales.
- **Post-RAMP estimated risk**: the co-occurrence of modeled fishing effort in the implementation period and modeled whale distributions in the implementation period. Post-RAMP estimated risk is intended to capture changes in entanglement risk due to RAMP's implementation.
- **Status quo estimated risk**: the co-occurrence of average fishing effort in the two baseline periods and modeled whale distributions in the implementation period. Status quo estimated risk is intended to simulate what entanglement risk would have been if the RAMP was not implemented.

Results

Table 1. Changes in blue and humpback whale entanglement risk following the RAMP's implementation. Fishing effort (related to magnitude of VMS pings) and entanglement risk metrics are reported for the implementation period and long and short baseline periods, which simulate the status quo if the RAMP had not been implemented. Percent (%) change indicates the change from the status quo, e.g. blue whale estimated entanglement risk decreased by 19.7% during the implementation period compared to the short baseline status quo. Unshaded values reflect summed values across months and grid cells. Fishing effort units are the number of VMS pings, but values have been adjusted and rescaled (see Methods) and do not reflect absolute magnitudes. Entanglement risk is unitless, and represents the product of fishing effort and whale distribution.

		Implementation period (Post-RAMP)	Long baseline (Status quo)		Short baseline (Status quo)	
				% change		% change
	Fishing effort	27.2	33.9	-19.7%	34.8	-21.6%
Estimated entanglement risk	Blue whale	3.7	6.3	-41.6%	4.5	-18.9%
	Humpback whale	7.3	9.9	-26.2%	7.1	2.1%

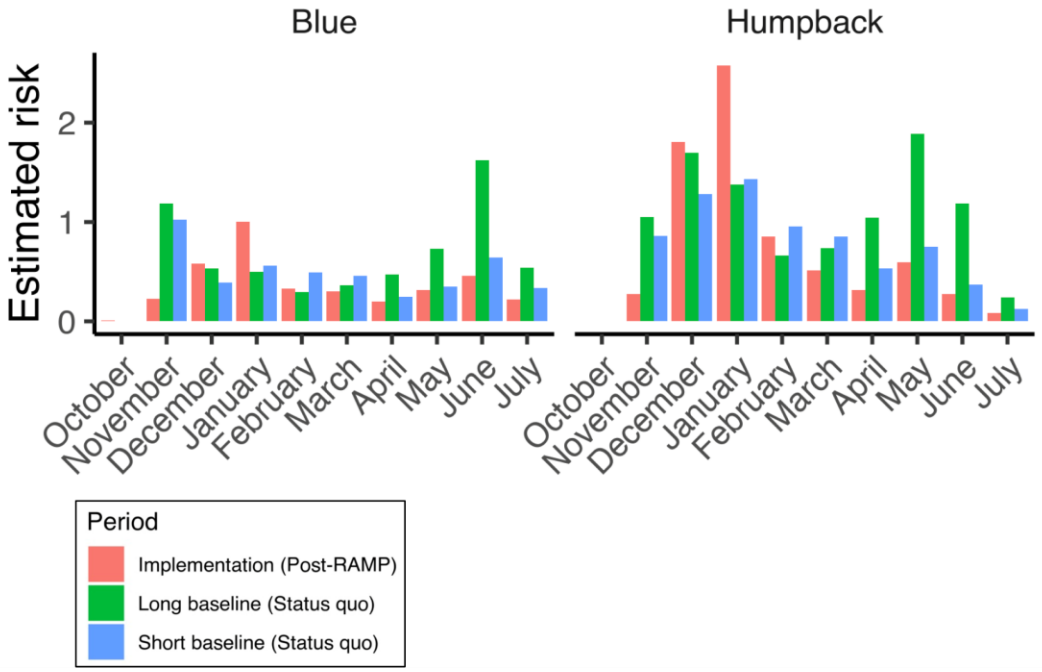

Figure 1. Estimated entanglement risk for blue and humpback whales by month (summed across grid cells).

Across all months and years, fishing effort decreased from 33.9 in the long baseline period to 27.2 in the implementation period (a percent change of -19.7%). Blue whale entanglement risk decreased from 6.3 in the long baseline periods to 3.7 in the implementation period (a percent change of -41.6%). Humpback whale entanglement risk decreased from 9.9 in the long baseline period to 7.3 in the implementation period (a percent change of -26.2%). The text above reflects results from the long baseline status quo; the same inferences can be made with regard to the short baseline status quo using the values in the last two columns of Table 1. Most of this estimated risk reduction for both species occurs in November and April-July, with estimated risk in the implementation period increasing in December and January relative to the long baseline period (Figure 1).

If CDFW decides to include inferences from this report in their Conservation Plan, we suggest a version of the following sentences:

Estimated entanglement risk to blue and humpback whales following the RAMP's implementation in 2020 is highly uncertain. Blue whale estimated risk decreased by 42% and 19% relative to the 2014-2019 and 2017-2019 baseline periods, respectively[1]*. Humpback whale estimated risk decreased by 26% relative to the 2014-2019 baseline period, and increased by 2% relative to the 2017-2019 baseline period. These findings rely on a simulated status quo of what risk might have been if the RAMP had not been*

[1] https://media.fisheries.noaa.gov/dam-migration/vms_complianceguide_may2020.pdf

implemented, and do not address how the change in risk to the whales varied month-to-month or between regions. [1]

Findings contributed by NOAA's Climate, Ecosystems, and Fisheries Initiative west coast decision support team.

Caveats

While these results represent rigorous scientific effort, there are a number of important caveats that may lead to high uncertainty. Species distribution models represent simplified versions of reality, and may over or under predict due to inherent biases and uncertainties in the model which were not integrated in the analyses reported above. Only a portion of Dungeness crab vessels are equipped with VMS, and thus our metric of fishing effort captures only a portion of the Dungeness fleet. Therefore, our measure of fishing effort depends on the assumption that VMS-equipped vessels are a representative sample of the entire Dungeness crab fishing fleet. An estimated 30-45% of landings, 10-35% of vessels, and 10-45% of revenue are represented in VMS data[1,2]. Additionally, NOAA's Office of Law Enforcement increased the VMS ping rate from 1 ping / hour to 4 pings / hour in May 2020 for many vessels[1]. Although ping rates in the baseline and implementation periods have been adjusted to account for this change (see Methods), results still may be impacted. Lastly, it is impossible to observe what fishing effort would have been if the RAMP had not been implemented, i.e. the status quo. Instead, status quo fishing effort in the implementation period has been simulated using average fishing effort in the baseline periods. While the reduction in entanglement risk in the implementation period could be due to the RAMPs implementation, it could also be due to independent changes in fishing effort between the baseline and implementation periods. The following scenarios could potentially lead to reduced entanglement risk independently of the RAMP's actions: fewer vessels participating in the fleet, a reduction in the market value of crab leading to vessels spending less time fishing, changes in fuel prices leading to vessels changing their fishing locations, changes in Dungeness crab distribution leading to vessels changing their fishing locations, etc. ***Methods***

Fishing effort

We estimated fishing effort using well established methods previously described in the literature[1–3], which link VMS telemetry data with port level fisheries landings data. For these analyses, we most closely followed the methods of Samhouri et al. (2021), where fishing effort was limited to Dungeness crab landed at California ports. Each year of Dungeness crab fishing ran from Nov. 1 - Oct. 31, even though the official start and end dates of any crab fishing season varies considerably from season to season.

Fishing effort based on VMS data have a known bias, given VMS transponders are not required aboard Dungeness crab boats; vessels that are required to use VMS throughout each fishing season hold a permit or participate in bottom trawl groundfish fishing, and a subset of these participate in the

Dungeness crab fishery. The bias is therefore toward larger vessels, as smaller vessels generally do not participate in the bottom trawl fishery (Liu et al. 2023).

VMS transponders record the geocoordinates of vessels at variable intervals, which had historically been on average once per hour. However, the NMFS Office of Law Enforcement that collects VMS data increased the sampling or "ping" rate to once every 15 minutes ca. 2020. We detected this increase in the median ping rate starting in January 2021. To account for the variable ping rate, we weighted each VMS ping from a given trip based on the mean ping rate from 2014 to 2020. For example, if a trip had a mean ping rate of four pings per hour, each individual ping within that trip was adjusted to ¼ ping. This adjustment made 2014 - 2020 VMS data directly comparable with 2021 - 2023 data. To calculate fishing effort, the adjusted VMS pings were overlaid on a 5 x 5 km grid, averaged at monthly intervals, and then normalized from 0 to1.

Limitations: First, the variable ping rate of VMS presents challenges for estimating fishing effort, especially since the ping rate was generally quadrupled starting in 2021. The method we developed for correcting for this increase in VMS sampling frequency should be considered preliminary and has not been fully vetted or scrutinized in the primary literature. Future iterations of this modeling effort could include a more rigorous and scientifically reviewed methodology that minimizes the potential for artifacts being introduced. Second, given the vessel length bias in VMS data and the fact that smaller boats are underrepresented, modeled changes in risk over time as well as relative risk for any location may not be representative of the true risk posed by the Dungeness crab fishery on vulnerable cetacean species.

Whale distributions

The blue and humpback whale models[3–5] were predicted across 2019-2023 to produce daily maps of each species' distribution. The blue whale model predicts in units of habitat suitability, while the humpback whale model predicts in units of density. To place both models on even footing, predictions from each model were rescaled from .0001 to 1. The rescaled predictions were then regridded to the 5 x 5 kilometer fishing effort grid. Real-time whale distributions were summarized by month and grid cell.

Entanglement risk

Entanglement risk is the product of whale distribution and fishing effort. Three different metrics of entanglement risk were calculated for each species, grid cell, and month in the implementation period:

- Post-RAMP risk: real-time whale distribution x real-time fishing effort (Fig. 2; Task 3)
- Status quo risk (short baseline): real-time whale distribution x climatological fishing effort from the short baseline period (Fig. 2; Task 2)
- Status quo risk (long baseline): real-time whale distribution x climatological fishing effort from the long baseline period (Fig. 2; Task 2)

The three risk metrics were summed across grid cells for each species to produce Figure 1. To produce Table 1, the three risk metrics were summed across grid cells and months for each species (unshaded

columns, Table 1). Percent change from status quo (shaded columns, Table 1) was calculated using each baseline as (post-RAMP risk risk - status quo risk)/status quo risk * 100 (Fig. 2; Task 4).

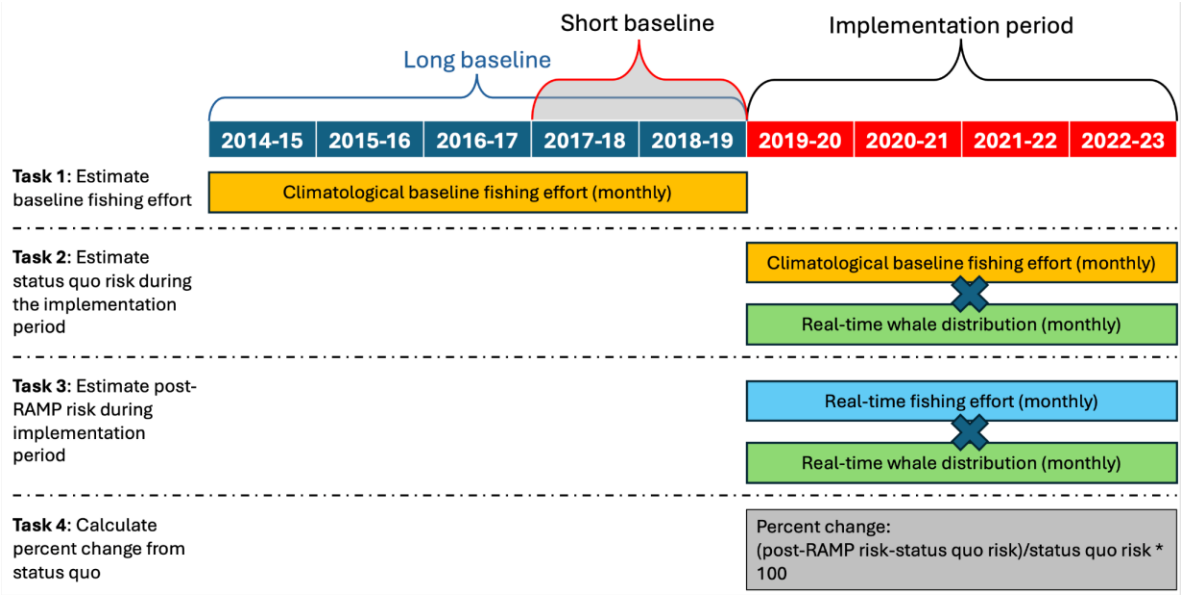

Figure 2. Methodological framework for quantifying entanglement risk reduction following the RAMP's implementation. The 'x' indicates multiplication; risk is the product of fishing effort and whale distribution. Climatological fishing effort: averaged by month across years, e.g. fishing effort averaged across all Januaries in the short baseline period. Real-time fishing effort: averaged by month, e.g. fishing effort averaged across January 2020.

References

1. Liu, O. R. *et al.* Mobility and flexibility enable resilience of human harvesters to environmental perturbation. *Glob. Environ. Change* **78**, 102629 (2023).
2. Feist, B. E., Samhouri, J. F., Forney, K. A. & Saez, L. E. Footprints of fixed-gear fisheries in relation to rising whale entanglements on the U.S. West Coast. *Fish. Manag. Ecol.* **28**, 283–294 (2021).
3. Samhouri, J. F. *et al.* Marine heatwave challenges solutions to human–wildlife conflict. *Proc. R. Soc. B Biol. Sci.* **288**, 20211607 (2021).
4. Welch, H. *et al.* Selection of planning unit size in dynamic management strategies to reduce human–wildlife conflict. *Conserv. Biol.* **38**, e14201 (2024).
5. Abrahms, B. *et al.* Dynamic ensemble models to predict distributions and anthropogenic risk exposure for highly mobile species. *Divers. Distrib.* **25**, 1182–1193 (2019).