

**Oregon Department of Fish and Wildlife
Marine Resources Program**

Semi-annual update on Oregon Dungeness Crab Commission Fishery Improvement (FIP) work plan

Assessment Period: February 2025 – July 2025

Report Date: August 2025

Goal/Performance Indicator	Actions	Due Date	Responsibilities	Progress
<p>5. Provide evidence that the fishery does not hinder recovery of ETP species.</p> <p>PI 2.3.1</p>	<p>A. Continue to participate in and support the Oregon Entanglement Advisory Committee (OEAC) to develop short- and long-term options for reducing whale entanglements in Dungeness crab fishing gear.</p> <p>B. Continue research to monitor whale distribution off the Oregon coast to identify whale hotspots.</p>	<p>Ongoing</p> <p>Ongoing (through at least June 2027)</p>	<p>Troy Buell (ODFW) and Crystal Adams (ODCC)</p> <p>Troy Buell (ODFW) and Leigh Torres (OSU)</p>	<p>A – ODFW convened an OEAC meeting during this reporting period on April 4, 2025. Discussion topics included the recent entanglement record and potential adaptive management measures in response, electronic monitoring progress, the Take Reduction Team, planning for a pop-up gear knowledge exchange and ODFW’s continued work on the Conservation Plan for reducing risk of entanglements. All meeting materials are posted here.</p> <p>B – ODFW and OSU continued work on a second Section 6 grant funded project titled ‘Enhancing Co-occurrence Assessment of Whales and Fishing Gear in Oregon Waters through Incorporation of Prey Data and Residency Analysis.’ This project has continued work to expand the initial modeling efforts by incorporating whale prey distribution for investigation of co-occurrence of whales and the crab fishery off Oregon. During this reporting period, a no-cost extension was requested by ODFW/OSU and granted by NOAA through June 30, 2026. The most recent progress report for this work is included as attachment A.</p> <p>Independent of Section 6 funding, ODFW and ODCC funded monthly aerial surveys for rorqual whales off Oregon throughout this reporting</p>

				<p>period. Also, within this reporting period ODFW and ODCC made an agreement to cost-share these surveys through June 2027.</p> <p>In this reporting period, OSU also wrapped up a whale scar rate analysis project titled 'Monitoring spatio-temporal changes in humpback whale entanglement rates through scar analysis, mark-recapture modeling, and enhanced community-based science.' This project was funded by federal Community Project Funding applied for by ODFW in 2022. The peer-reviewed publication is posted here.</p>
	C. Continue to develop the Conservation Plan for endangered and threatened whales.	Ongoing	Troy Buell (ODFW)	<p>C – ODFW continues development of a comprehensive conservation plan (CP) to minimize the risk of marine life entanglement in commercial Dungeness crab gear. The CP will be the main supporting document in the application for an incidental take permit (ITP) application to the National Marine Fisheries Service (NMFS). During this reporting period staff began meeting with NMFS Office of Protected Resource biologists every two weeks to discuss feedback on revisions to the CP. ODFW has continued to evaluate this feedback and revise the draft CP to address NMFS guidance when possible. ODFW also met with OEAC to discuss revisions to the CP, see goal 5A.</p>
6. Demonstrate that there is a strategy in place that is designed to ensure the fishery does not pose a risk of serious or irreversible harm to the habitats.	A. Develop and implement new technologies to monitor crab vessel locations and compliance with closed areas.	Dec 2026	Troy Buell (ODFW)	<p>A - ODFW has continued to work with third-party software developers on a vessel tracking integrated electronic logbook application to incorporate users feedback from phase 2, improve the performance of the application and incorporate a fourth VMS model. ODFW has also continued to work on integrating the new data stream into internal databases and with</p>

<p>PI 2.4.2</p>				<p>PSMFC to develop a data dashboard to view and use the data in near real-time.</p> <p>In this reporting period ODFW continued planning for the NOAA Fishery Information Systems (FIS) grant project to finalize a production logbook application and implement the system broadly within the Oregon crab fleet by offering partial reimbursement for VMS units purchased. Work on this grant will begin when funds are received, which is uncertain at this time.</p> <p>ODFW remains committed to working with industry to test electronic monitoring (EM) systems for vessel tracking and developing procedures for how systems can be used to provide near real-time fishery data by the 2026-27 crab season (see Section 5.3.3.3 starting on page 94 of the draft CP titled “Electronic Monitoring”).</p>
<p>7. Demonstrate that Information is adequate to determine the risk posed to the habitat by the fishery.</p> <p>PI 2.4.3</p>	<p>A. Continue research and monitoring of coastal habitats identified in the Oregon Nearshore Strategy, including:</p> <ul style="list-style-type: none"> • Survey of seafloor structures and habitat composition • Examination of species, communities, and habitat relationships to habitat monitoring priorities. 	<p>Ongoing</p>	<p>Scott Marion (ODFW)</p>	<p>A - Nearshore shallow rocky reef habitats in previously un-mapped regions of Rogue Reef, off Gold Beach, were surveyed in June 2025 using a multibeam sonar system. This completes a bathymetry mapping survey of the Rogue Reef region initiated in 2024.</p> <p>In May 2025 in the Port Orford area, 34 remotely operated vehicle video transects were conducted to assess ecological condition at Redfish Rocks Marine Reserve and its associated comparison areas.</p> <p>Analyses were conducted assessing kelp abundance and distribution changes since 2010. A report is in preparation analyzing aerial survey data collected in 2022 and 2024.</p>

Attachment A

NOAA Species Recovery Grant Semi-Annual Progress Report

Grant number: NA22NMF4720105

Project title: Enhancing Co-occurrence Assessment of Whales and Fishing Gear in Oregon Waters through Incorporation of Prey Data and Residency Analysis

Grantee name: Oregon Department of Fish and Wildlife

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Dates of the award period: 7/1/2022-6/30/2025

Dates covered by the progress report: 1/1/2025-6/30/2025

Description of the tasks scheduled for the reporting period and tasks accomplished during the reporting period:

As described in the project proposal, the Oregon Department of Fish and Wildlife (ODFW) planned for most of the work under this award to be conducted by Oregon State University (OSU) under an Intergovernmental Agreement (IGA) establishing a contractual relationship between the two parties, which was executed on August 5, 2022. This report addresses tasks scheduled during the reporting period as outlined in *Figure 3. Milestone timeline of proposed project* of the project proposal.

Data collection and compilation

Step 1: Vessel-based endangered species survey and prey data collection

This phase of the project is complete. All data to be used in the subsequent project steps has been collected previously.

Step 2: Endangered species helicopter transects

This phase of the project is complete. All data to be used in the subsequent project steps has been collected previously.

Step 3: Fishery effort mapping

ODFW completed data entry and Quality Control/Quality Assurance of Oregon crab logbook data and received logbook and fish ticket data from WDFW for the 2022-2023 crab season. This additional season of data was integrated with prior season's data and monthly fishing effort raster layers were produced from the combined dataset following the methods of Derville et al. (2023).

ODFW continued to develop logbook data processing, mapping, and scaling methods for additional fixed gear fisheries including groundfish, hagfish, spot prawn, and nearshore fish during the reporting period. Data processing for spot prawn and hagfish fisheries is complete, raw effort maps have been produced, and spatially explicit estimates of gear density are nearly complete. Data processing and estimation of gear density has proven more challenging for groundfish data due to the multi-species, multi-fishery nature of the data, but is progressing.

ODFW determined that halibut logbook data held by the International Pacific Halibut Commission is not available without permission from each fisher who submitted the data and decided not to pursue this further. ODFW determined that nearshore logbook data may not be useful for estimating the number of vertical lines in the water without supplementary data. Through conversations with fishery participants, it became apparent that many using longline gear were recording one start and one end location for the day rather than for each longline set, such that a single "set" in the logbook data represents an unknown number of vertical lines between the start and end point. This fishery consists of only 10-15 boats fishing typically inside of 30 fathoms, so it does not overlap with primary humpback whale habitat to a great degree. Given the time required to collect supplemental information, ODFW has decided not to pursue further for this project.

Step 4: Small boat surveys

This phase of the project is complete. All data to be used in the subsequent project steps has been collected previously.

Step 5: Compilation of environmental predictor variables

This step is completed, and analysis can now proceed with Step 13 (Generate roqual SDMs).

Outreach and Engagement

Step 6: Promote reporting of whale sightings

This phase of the project is complete. All data to be used in the subsequent project steps has been collected previously.

Step 7: Develop and manage fleet alert system

This phase of the project is complete.

Step 8: Develop R shiny app to predict whale distribution on a weekly scale

OSU currently has no progress to report. OSU anticipates this work to primarily occur toward the end of the project, once whale predictive models are being finalized.

Step 9: Raise awareness of issue and project

Scientific presentations:

Leigh Torres met with the scientists and managers associated with the NOAA West Coast Take Reduction Team on January 24, 2025 to discuss the OPAL project and how outputs could be integrated into NOAA's efforts to develop an entanglement mitigation app.

NOAA Scientific Research Group (SRG) meeting – April 16, 2025: Lindsay Wickman and Leigh Torres gave the presentation “Using a Bayesian capture-recapture model to estimate DPS proportions of humpback whales along the N-CA/OR coast by spatial and temporal zone,” related to research completed under Step 18.

Leigh Torres, Lindsay Wickman, and Rachel Kaplan presented work on the OPAL and SLATE projects at the Marine Mammal Institute Monthly Meeting in March 2025, to an audience of ~30 professors, students and staff.

Public outreach:

Instagram posts (by the account: @gemm_lab) related to this work were made on June 27, June 23, June 9, May 16, April 9, February 5, and February 3. Posts were related to STEM outreach cruises, survey efforts and data, and researchers involved in the OPAL project.

Marine Science Day – April 12, 2025: Lindsay Wickman, Rachel Kaplan, and other members of the GEMM Lab volunteered at a booth to educate the public about current research on whales along the Oregon Coast. A child-friendly activity was created to educate the public about research on whale entanglement.

Spatial and ecological analysis of prey and whales

Step 11: Analysis of krill data

This phase of the project is complete. All data to be used in the subsequent project steps has been collected previously.

The following three manuscripts have been published:

1. Kaplan RL, Derville S, Bernard KS, Phillips EM, Torres LG (2024) Humpback-krill relationships are strongest at fine spatial scales in the Northern California Current region. *Marine Ecology Progress Series* 729:219-232. <https://doi.org/10.3354/meps14510>
2. Kaplan RL, Bernard KS, Derville S, Fisher JL, Phillips EM, Daly EA, Warren JD, Torres LG (2025) Krill swarm biomass, energetic density, and species composition drive humpback whale distribution in the Northern California Current. *ICES Journal of Marine Science* 82 10.1093/icesjms/fsaf005
3. Derville S, Fisher JL, Kaplan RL, Bernard KS, Phillips EM, Torres LG (2025) A predictive krill distribution model for *Euphausia pacifica* and *Thysanoessa spinifera* using scaled acoustic backscatter in the Northern California Current. *Progress in Oceanography* 231:103388. <https://doi.org/10.1016/j.pocean.2024.103388>

A final paper is now in review in *Scientific Reports*, “Krill swarm structure drives trophic partitioning in sympatric baleen whale species on the Northern California Current foraging grounds” (attached here as an Appendix). The abstract of this manuscript is as follows:

Krill swarm structure drives trophic partitioning in sympatric baleen whale species on the Northern California Current foraging grounds

By Rachel L. Kaplan, Kim S. Bernard, Solène Derville, Elizabeth M. Phillips, Joseph D. Warren, and Leigh G. Torres

Abstract

For sympatric species, niche differentiation may manifest through resource selection or as spatiotemporal partitioning of shared resources. Body size, physiology, and morphology influence the tactics that predators, such as baleen whales, use to meet their energetic needs. Blue, fin, and humpback whales require rich prey patches, such as the extensive swarms that

krill form, to offset the energetic burden of foraging given their large body sizes. Krill swarm characteristics (e.g. length, height, biomass, etc.) may be important drivers of whale foraging efficiency and therefore habitat selection. We used a Random Forest model to classify blue, fin, and humpback whale species based on characteristics of nearby krill swarms acoustically detected in the Northern California Current. Swarm characteristics associated with each whale species including mean depth, proportion of *Thysanoessa spinifera*, proportion of swarm occupied by krill rather than water, and internal heterogeneity reflected habitat selection and breadth of species' trophic niches. Despite overall good classification performance (model accuracy = 0.79), erroneous predictions revealed the difficulty of differentiating the niches of generalist predators, humpback and fin whales, *versus* blue whales, a specialist predator. Our results suggest krill swarm characteristics contribute to resource partitioning between baleen whale species on shared foraging grounds

Step 13: Generate rorqual whale SDMs and Step 14: Evaluation of whale SDMs

The final dataset implemented in the SDM analysis is composed of 236,958 km of survey effort conducted over 404 days, including 2,327 groups of whales (3,883 individuals) observed. Environmental data (provided by ROMS), fish data (provided by Barbara Muhling from NOAA) and krill data (from Step 11 of this project) were downloaded and incorporated in the workflow at the right spatio-temporal scale.

OSU has produced a range of distribution models (Fig. 1) for humpback whales, blue whales, fin whales, and all rorqual whales combined (including unidentified rorquals). Each of the species was tested as a response variable, whose distribution was modelled in relation to different sets of explanatory variables: fish (sardine, anchovy, and herring), krill (*Thysanoessa spinifera* and *Euphausia pacifica*), abiotic variables (eight oceanographic ROMS variables and two topographic variables), krill and abiotic, fish and abiotic (humpback and fin whales), and fish and krill interaction (humpback and fin whales).

Modelling framework

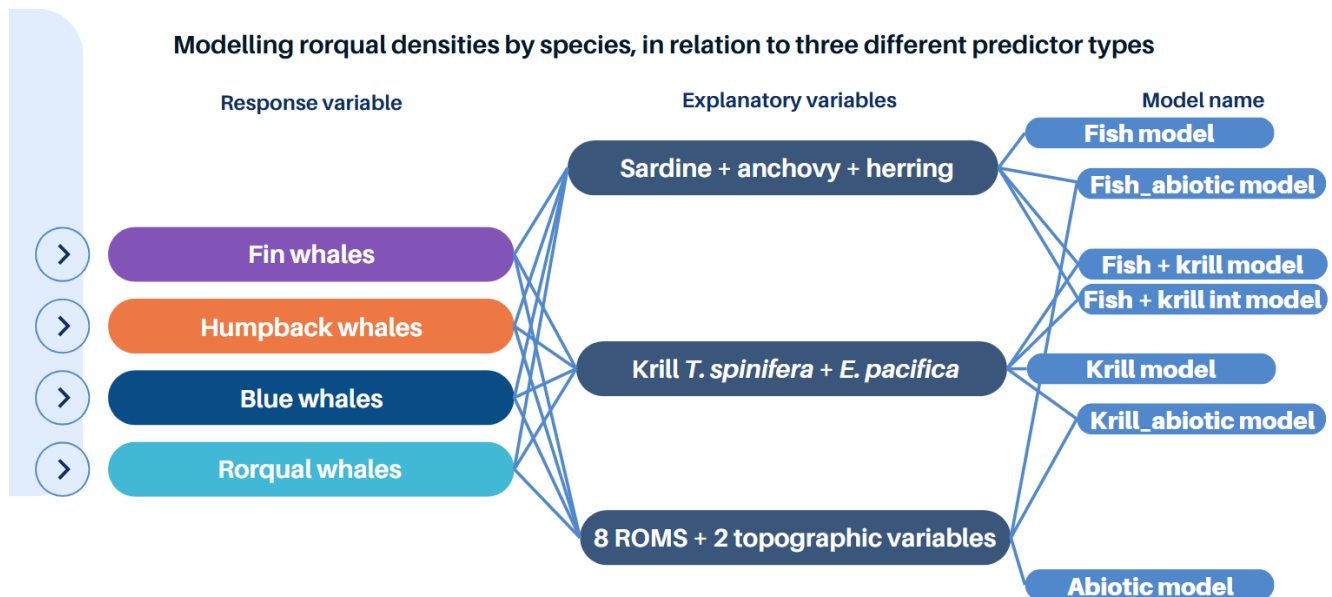


Figure 1: Modelling framework for Generalized Additive Models applied to whale density data in relation to various explanatory variables. This framework aims to study the hypothesis that prey data can improve the predictive performance of whale distribution models compared to using only abiotic environmental variables.

Each SDM model type predicted different distribution patterns for each rorqual whale (Figs. 2–4). Determining the “best” model is not straightforward as areas predicted as whale hotspots varies by SDM model type (Fig. 5) and by performance metric (Fig. 6). Overall, the krill_abiotic model appears best for blue whales, although it has similar performance to the abiotic model. Furthermore, the fish + krill interaction model appears to have the best overall performance for fin whales. The fish + krill interaction model has strong overall performance metrics for humpback whales, with the abiotic and the krill_abiotic models still performing well in the cross-validation tests during model training.

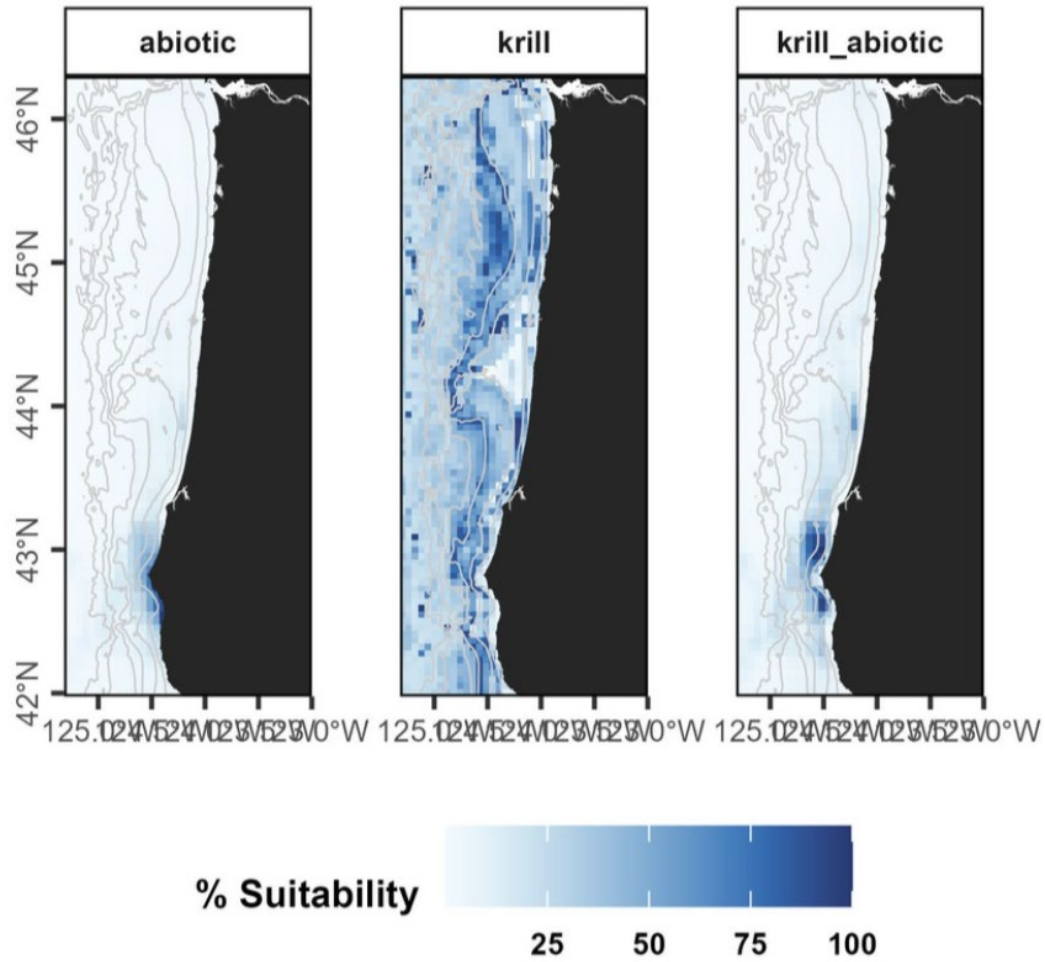


Figure 2: Monthly predictions of blue whale habitat suitability for the month of September 2023. Predicted whale densities were normalized to 0-100% by month, by model and by species.

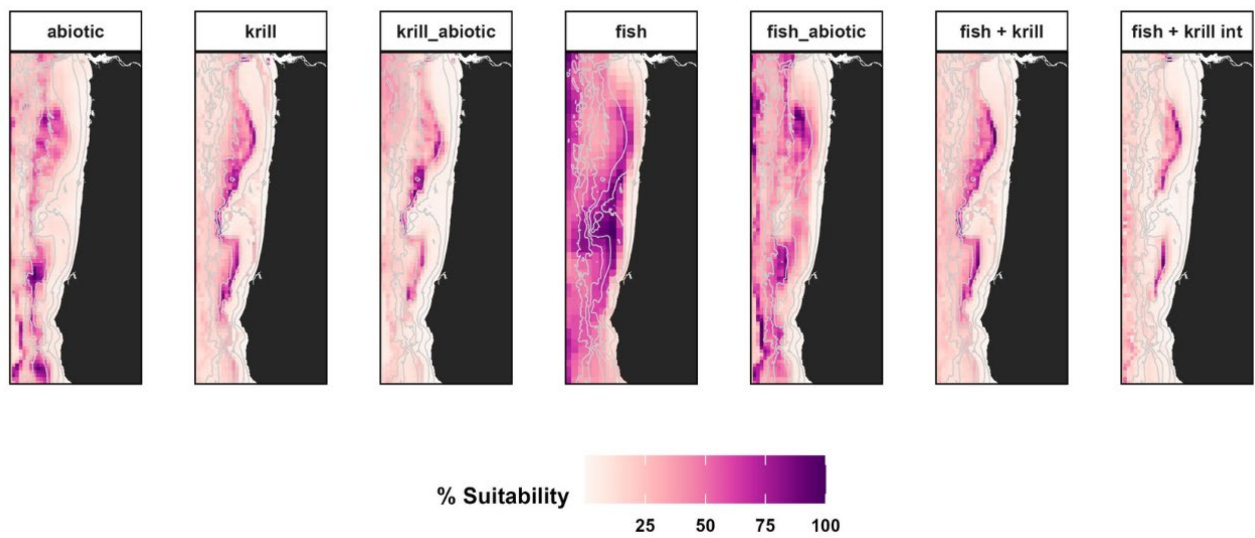


Figure 3: Monthly predictions of fin whale habitat suitability for the month of September 2023. Predicted whale densities were normalized to 0-100% by month, by model and by species.

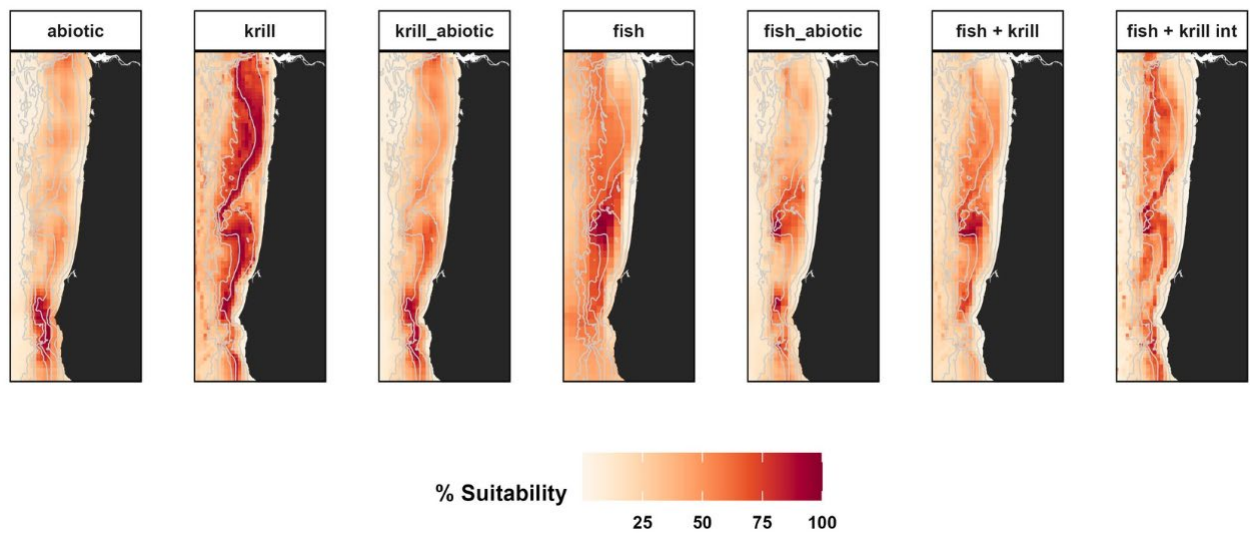


Figure 4: Monthly predictions of humpback whale habitat suitability for the month of September 2023. Predicted whale densities were normalized to 0-100% by month, by model and by species.

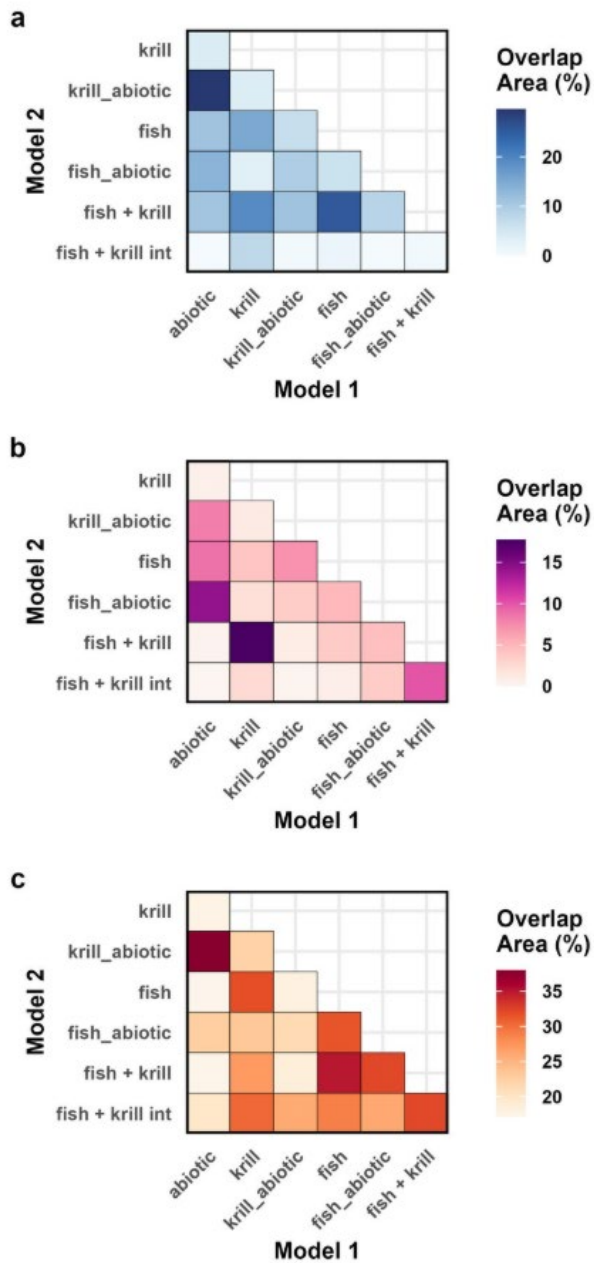


Figure 5: Percent of area overlap between monthly average hotspots of whale predictions calculated across 9 years (2016-2024) for blue (a), fin (b), and humpback whales (c). The color scale by species indicates the result of pairwise comparisons between each combination of models reported on the x and y axes.

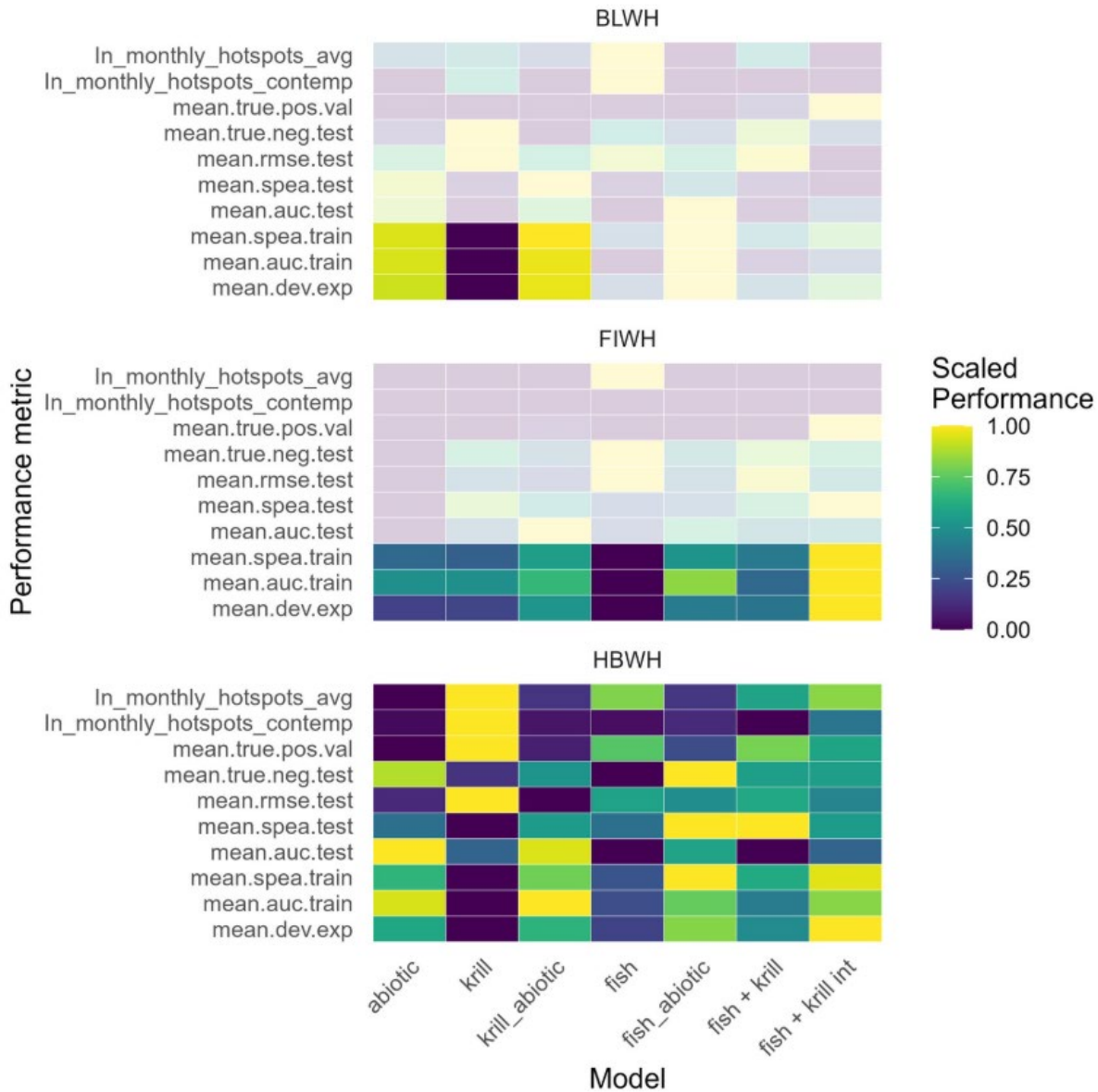


Figure 6: SDM performance metrics (scaled for comparison) for each model type (X-axis) and performance metric (Y-axis) by species (top panel = blue whale; middle panel = fin whale; bottom panel = humpback whale). The top three rows are performance metrics derived from external evaluation of the model predictions. The next four rows (ending in “test”) are performance metrics derived from the model test cross-validation. The last three rows are performance metrics calculated on the training dataset during cross-validation. Yellow values indicate relatively higher performance, while purple values indicate relatively lower performance. White faded boxes mask the metrics and models considered less relevant for model evaluation: For blue and fin whales we disregarded the external validation metrics and the test cross-validation metrics because these are impaired by low sample size. For blue whales,

we also exclude models including fish predictors as these are not known as potential prey for this rorqual species.

Using rorqual sightings data provided by the collaborators during leatherback surveys in the study region (Karin Forney and Scott Benson) and the GEMM Lab (collected during non-survey effort – e.g., small boat work or other projects), we amassed a sizable validation dataset for quantitative performance assessment of the humpback whale SDMs (Fig. 6). Only a few fin and blue whales were observed in these validation datasets, which did not provide a robust sample size to test the performance of the SDMs quantitatively. However, model performance was qualitatively assessed by plotting species specific (blue, fin, and humpback) monthly predictions and overlaying the validation sightings (Figs. 7, 8, 9).

The blue whale abiotic_krill SDM predictions show a preference for nearshore and southern waters, north and/or south of Cape Blanco, and show relatively good visual overlap with the few available validation points. The fin whale fish + krill interaction SDM prediction shows a preference for habitat off the continental shelf break, with a hotspot off Newport/Lincoln City and North Bend, and low visual overlap with the very few validation points available. The humpback whale fish + krill interaction SDM prediction shows a preference for habitat in central Oregon, particularly between the 100 and 200 m isobaths, and good visual overlap with validation sightings near the shelf break but perhaps not as well on the shelf.

Species-specific distribution patterns

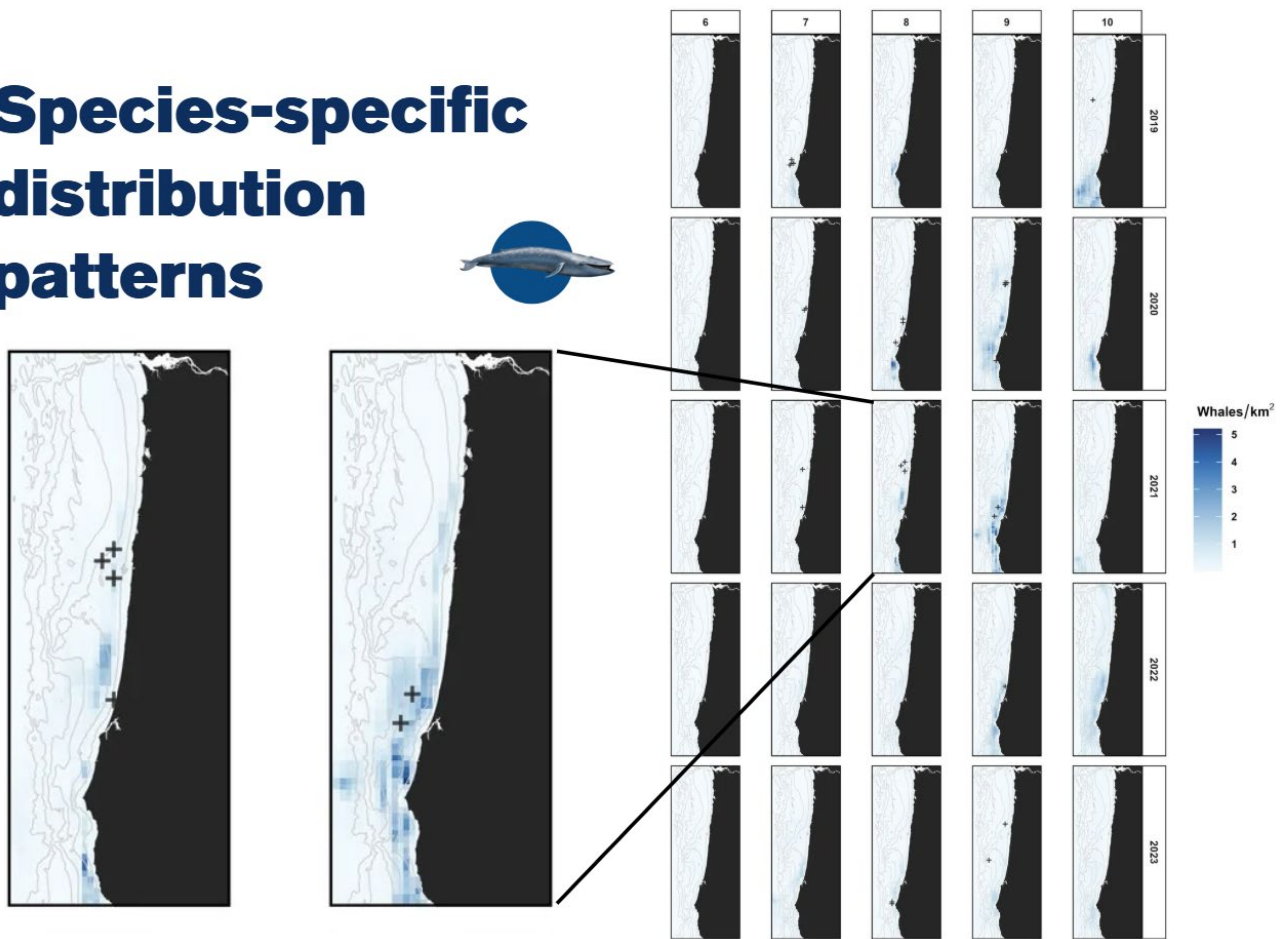


Figure 7: Monthly predictions (June – October) of blue whale density by the *krill_abiotic* model for the period 2019-2023 with validation sightings of blue whales (crosses) overlaid to qualitatively assess predictive performance. Two months (August and September 2021) are zoomed in on for closer examination.

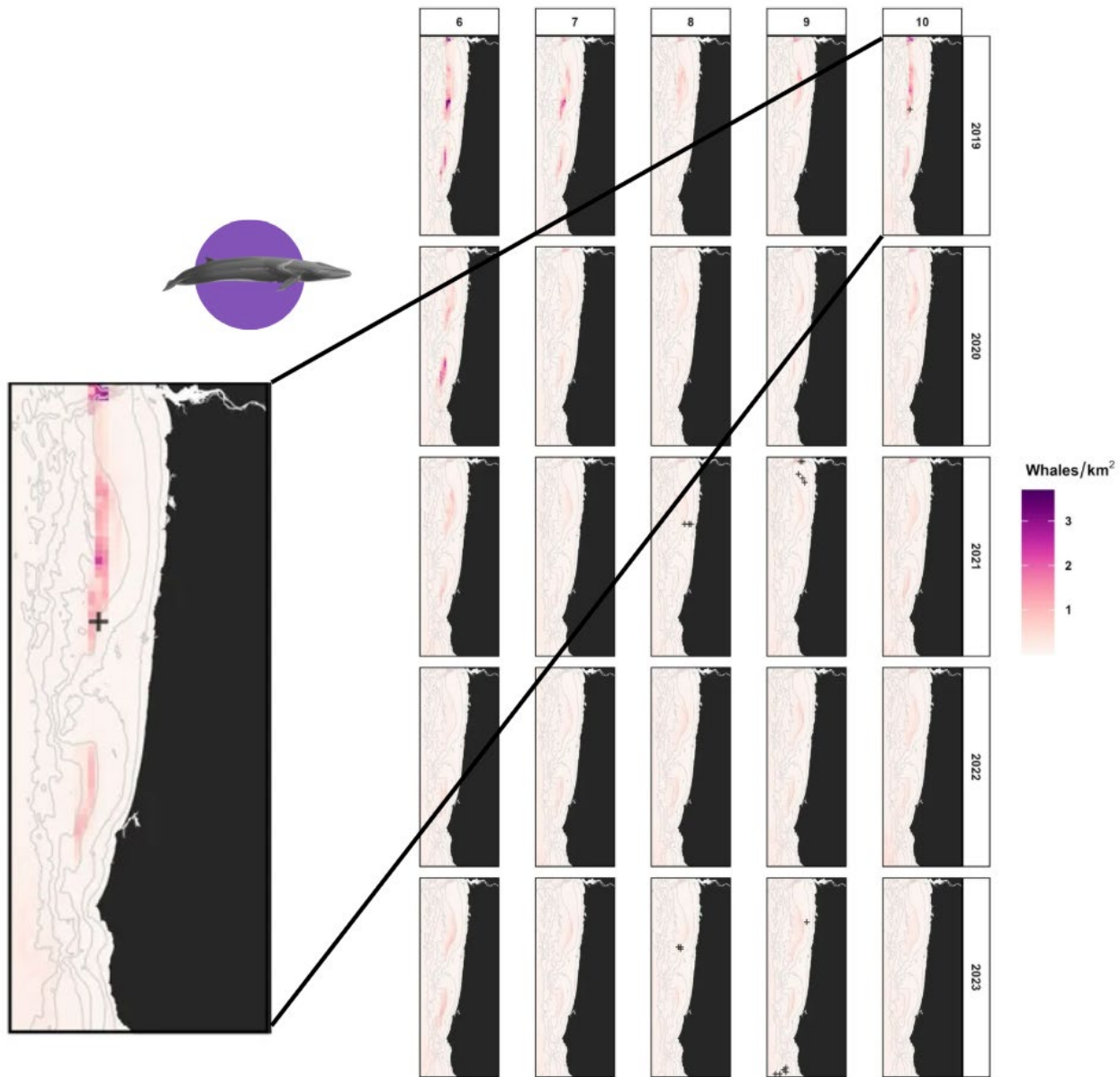


Figure 8: Monthly predictions (June – October) of fin whale density by the fish + krill interaction model for the period 2019-2023 with validation sightings of fin whales (crosses) overlaid to qualitatively assess predictive performance. October 2019 is zoomed in on for closer examination.

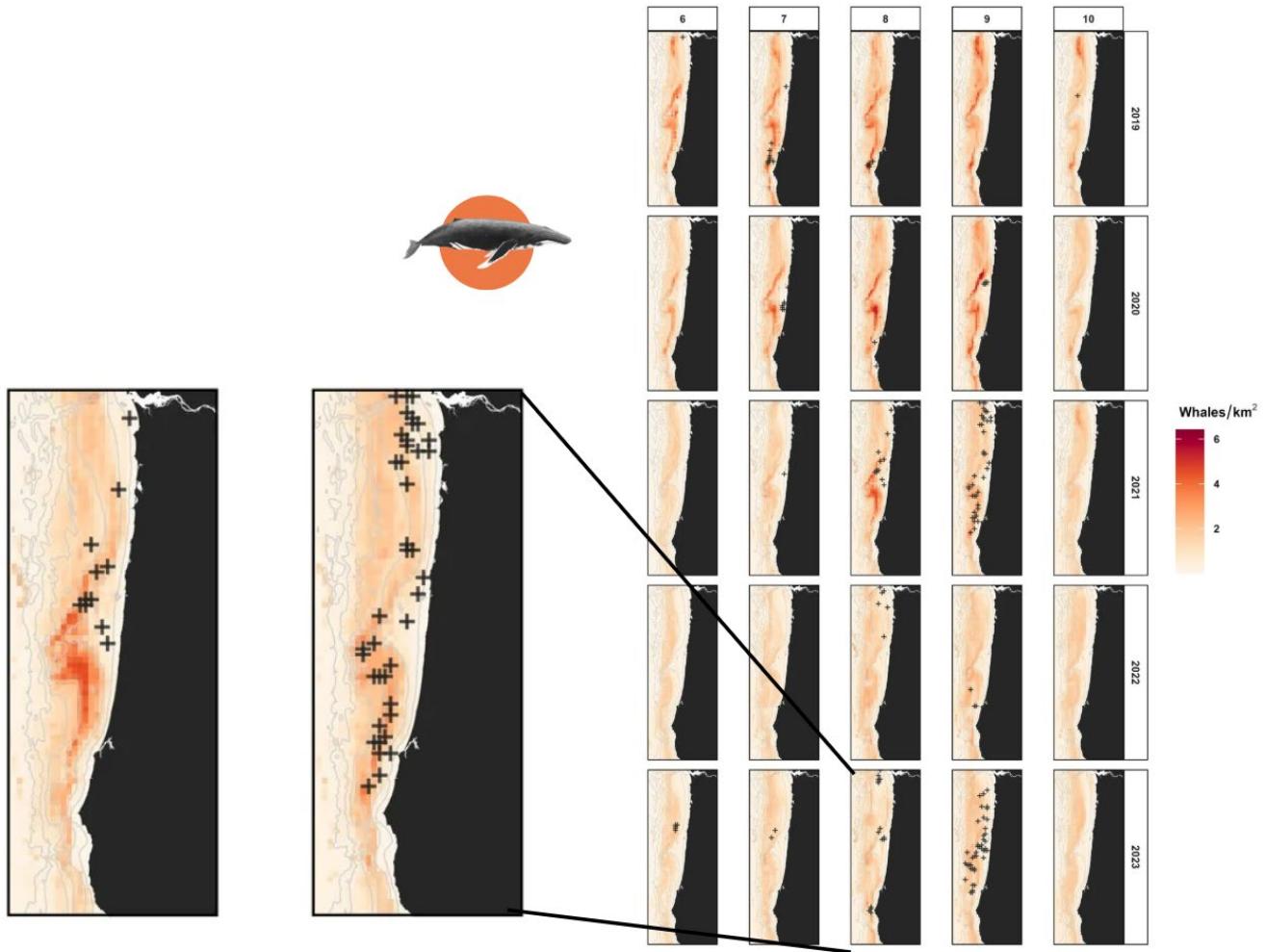


Figure 9: Monthly predictions (June – October) of humpback whale density by the fish + krill interaction model for the period 2019-2023 with validation sightings of humpback whales (crosses) overlaid to qualitatively assess predictive performance. Two months (August and September 2023) are zoomed in on for closer examination.

Our next steps will be to produce monthly predictions from 2011-2024 for the co-occurrence analysis to be conducted (Step 15). In consultation with ODFW, we will produce SDM predictions for each species using the abiotic model, and the krill_abiotic model for blue whales, and the fish+krill interaction model for fin and humpback whales. Because whale distribution predictions using the R shiny app (Step 8) will not be able to utilize fish layers (they will not be available from the Environmental Research Division's Data Access Program (ERDDAP) going forward), these whale predictions will need to be based on abiotic or krill layers. Thus, in Step 15 we will evaluate whether fisheries overlap rates by zone and time period vary markedly between the abiotic and prey informed model predictions. If similar fisheries overlap rates are derived, this result would lend justification for producing whale predictions with the R shiny app based on abiotic SDMs.

Step 15: Co-occurrence modeling of whale distribution and fishing effort

This phase of the project is starting now that the SDM predictions are complete. Please see last paragraph in Step 14 for details.

Step 16: Assess drivers of inter-annual entanglement risk

This phase of the project is starting now that the SDM predictions are complete.

Step 17: Humpback whale genetic DPS assignment

This phase of the project is complete. All data to be used in the subsequent project steps has been collected previously.

Step 18: Spatial Fidelity to Feeding Areas

We finalized our analysis approach for Step 18 in April 2025. This work was written up as a manuscript draft during May and June 2025, which will be submitted for publication during the next reporting period. A summary of key findings and management implications derived from the draft publication are provided below.

Summary:

Mexico was consistently the highest DPS proportion in our study region, but the relative proportions of each humpback whale DPS (Mexico, Central America, and Hawaii) varied spatially across the three zones in our study region, and temporally across four time periods within the foraging season. While DPS proportions were relatively similar among zones during the first half of the foraging season (May–Jun and Jul–midAug), relative proportions of the Mexico and Central America DPS differed from south to north (Mexico increased north, Central America decreased north) during the latter half of the season (midAug–Sep and Oct–Nov). Estimates of site fidelity were similar for all three DPS, suggesting that although the relative proportions of each DPS differed, individuals from the Mexico, Central America, and Hawaii DPS used the region similarly. Our estimated DPS proportions have current management applications, but our analysis showing a potential northerly shift in the latitude of sightings of Mexico and Unknown DPS individuals recently added to the dataset highlight a need for continued monitoring of metapopulation structure in this region. Management strategies should continue to be refined by regularly reassessing these DPS proportions, as they may shift due to separate population growth rates and shifts in the distribution of each DPS.

Our progress on Step 18 is further detailed in the following sections:

1. Photo-ID dataset and integration with MOSAIC

2. Capture-recapture model to estimate proportion DPS by spatial and temporal zones
3. Comparison of site fidelity among DPS
4. Latitudinal changes in sighting distribution: 2016–2024

1. *Photo-ID dataset and integration with MOSAIC*

OSU and Cascadia Research Collective (CRC) compiled humpback whale photo-ID data collected between the Oregon-Washington border and Cape Mendicino, California. This study region extends south of OPAL’s study region of just Oregon waters because we integrated this analysis with data collected through a Department of Energy (DOE) funded project to the Marine Mammal Institute at OSU (with Torres, Baker, and Calambokidis as Co-PIs). This DOE project, entitled “Marine Offshore Species Assessments to Inform Clean Energy (MOSAIC)”, includes Oregon waters and extends to Cape Mendicino with aims to inform the siting of offshore wind energy development. Integration of the OPAL and MOSAIC projects enables a larger dataset for both projects, analyses to be aligned, and completion of unique goals for each project. (Please see schematic in Fig. 10 to see how these projects are being integrated).

We received the full photo-ID dataset from CRC in January 2025. The final photo-ID dataset provided by CRC included sighting data spanning 1990—2024, comprised of 1,492 individuals (Fig. 11). Meetings were held to discuss our analysis approach on January 9, February 24, March 24, April 8, and April 28, 2025 (involving Leigh Torres, Lindsay Wickman, John Calambokidis, Scott Baker, Franca Eichenberger, and Debbie Dietrich). After finalizing our analysis approach at the end of April 2025, we have written up the results of Step 18 into a draft manuscript that will be submitted to coauthors to review by July 31, 2025.

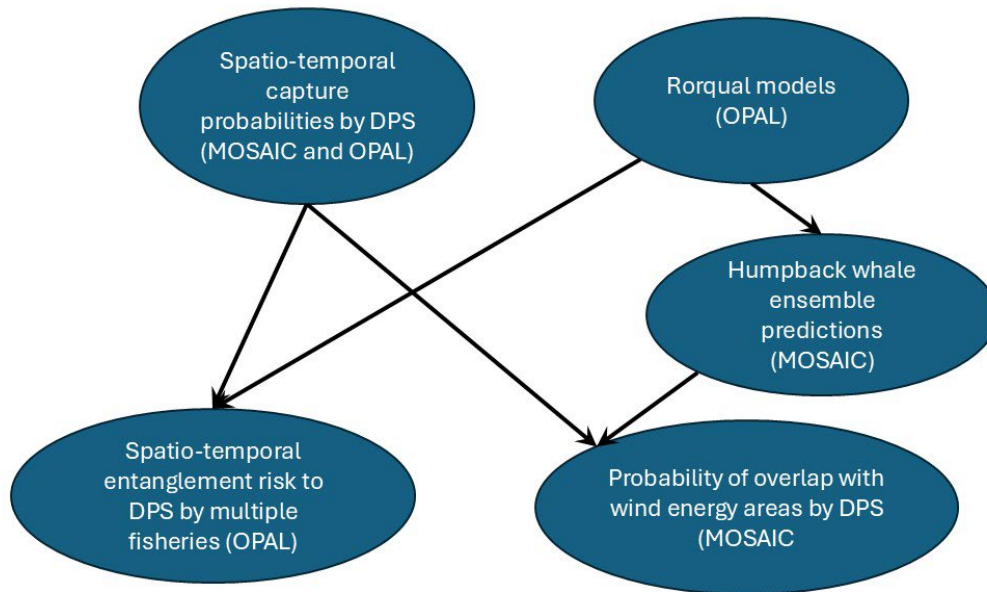


Figure 10. Schematic of how data analyses and outputs are integrated and shared between the OPAL and MOSAIC projects to meet multiple research objectives.

2. Capture-recapture model to estimate proportion DPS by spatial and temporal zones

Methods

We used a hierarchical Bayesian capture-recapture model formulation of the Cormack-Jolly-Seber open population model (Cormack, 1964; Jolly, 1965; Seber, 1965) to estimate a capture probability specific to each DPS (Mexico, Central America, and Hawaii), zone (N-OR, S-OR, and N-CA), and four time periods within the foraging season (between May 1 and November 31). Capture-probability was subsequently scaled by the number of individuals observed across the study period to estimate how proportions of individuals from each DPS varied by time period and zone.

The four time-periods were created using a Jenks natural breaks function on the number of sightings per Julian day of year (doy) in R (Jenks, 1967; R Core Team, 2023). Final time periods were as follows:

- May-Jun (doy: 125-180)
- Jul-midAug (doy:181-230)
- midAug-Sep (doy:231-272)
- Oct-Nov (doy: 273-334)

Zone boundaries were chosen based on biogeographic markers and political boundaries (Fig. 11):

• **Northern Oregon (N-OR):** bounded by the Columbia River (latitude: 46.3 N) in the north and the Cape Blanco bio-geographic boundary (latitude 43.5 N) in the south. Instead of placing the boundary at Cape Blanco itself, we chose this latitude to account for the upwelling retention zone north of Cape Blanco, as described by Schroeder et al. (2022).

• **Southern Oregon (S-OR):** bounded by the Cape Blanco bio-geographic boundary (latitude 43.5 N) in the north, and the political boundary of Oregon and California (latitude 42.0 N) in the south. In addition to being a useful boundary for management purposes, this boundary was also commonly used during photo-ID surveys in small boats (i.e., researchers rarely sampled across this boundary within a given day).

• **Northern California (N-CA):** bounded by the OR/CA border (latitude 42.0 N) in the north, and Cape Mendocino, CA (latitude 40.25 N) in the south.

During our meetings with the Cetacean Conservation Genomics Lab (Scott Baker, Debbie Steel, and Franca Eichenberger) and John Calambokidis, we determined that combining photo-

ID sightings with genetics to assign DPS was not feasible, due to methodological differences and challenges resolving DPS when both genetics and sighting history data were available. Therefore, we chose to assign DPS based on sightings of whales in breeding grounds, using sightings from the public database Happywhale (Cheesman et al., 2023) that were curated and provided to us by CRC.

DPS assignment based on sightings is complicated by the fact that Mexico lies within the migratory path of whales traveling to/from Central America. Therefore, whales were assigned to a DPS based on the following hierarchical decision-making structure, which took a conservative approach by prioritizing assignment to the Central America DPS (given its Endangered status):

- **Central America:** If an individual was ever captured (i.e., encountered and successfully photographed) in the Central America breeding ground, it was assigned to the Central America DPS, regardless of the quantity of sightings in Mexico or Hawaii breeding grounds.
- **Hawaii:** All individuals captured at least once in Hawaii, but never in Central America or Mexico breeding grounds, were assigned to the Hawaii DPS.
- **Mexico:** Individuals captured at least once in Mexico, but never in Central America, were assigned to the Mexico DPS. If an individual was captured in both Hawaii and Mexico, it was assigned to the Mexico DPS (regardless of the quantity of sightings in Hawaii).
- **Unknown:** Individuals with no sighting records on a breeding ground were assigned an "Unknown" DPS status. In the Bayesian capture-recapture model, individuals with Unknown DPS were treated as a latent state variable, so that the model assigned these individuals to a known DPS (Central America, Hawaii, or Mexico) during each simulation.

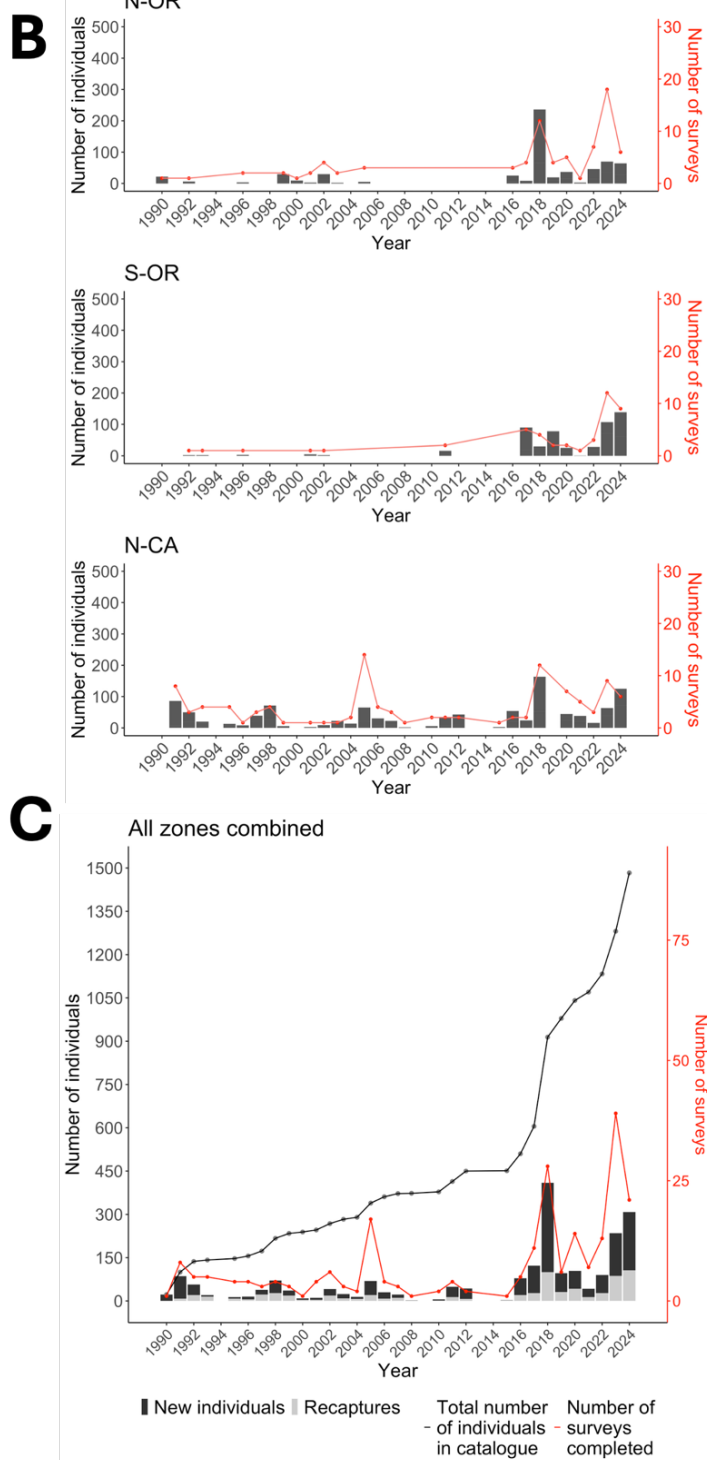


Figure 11: Summary of photo-ID data from 1990–2020 for humpback whales in the study region (Cape Mendocino, CA to Columbia River, OR). (A) Zone boundaries and locations of captured (i.e., sighted and photographed) humpback individuals, (B) number of individuals captured and number of daily surveys conducted during each year in each of the three zones

(N-OR, S-OR, and N-CA), (C) discovery curve (the cumulative number of individuals in the catalog, represented as a black line), the total number of unique individuals sighted each year (represented by stacked bars with the proportions of new individuals, in black, vs. recaptured individuals, in grey), and the number of daily surveys (during which at least one humpback whale was photographed, represented as a red line).

Results

The hierarchical Bayesian capture-recapture model estimated that in all three zones in our study region (N-OR, S-OR, and N-CA), the highest proportion of individuals belonged to the Mexico DPS (the median proportion for all zones and time periods ≥ 0.63), followed by Central America (Table 1, Fig. 12). The Hawaii DPS consistently represented the lowest proportion of individuals across all zones and time periods (<0.05), and in N-CA during Oct–Nov, our model estimated that no individuals from the Hawaii DPS were present (Fig. 12).

Whereas similar proportions of the Central America DPS were found across the three zones during the first two time periods, our model estimated decreasing proportions of Central America DPS from south to north during the last two time periods (midAug–Sep and Oct–Nov) with simultaneous increasing proportions of Mexico DPS (Fig. 12). In both of these later time periods, the proportion of Central America DPS in N-CA was slightly higher than in S-OR, and the proportion of Central America DPS in S-OR was generally higher than in N-OR. For example, the proportion of Central America DPS in N-CA was higher than S-OR in 88% of iterations for midAug–Sep and 81% of iterations for Oct–Nov. The proportion of Central America DPS in S-OR was higher than N-OR in 80% of iterations during midAug–Sep, and during Oct–Nov our model estimated almost no individuals from the Central America DPS were present in N-OR (Fig. 12).

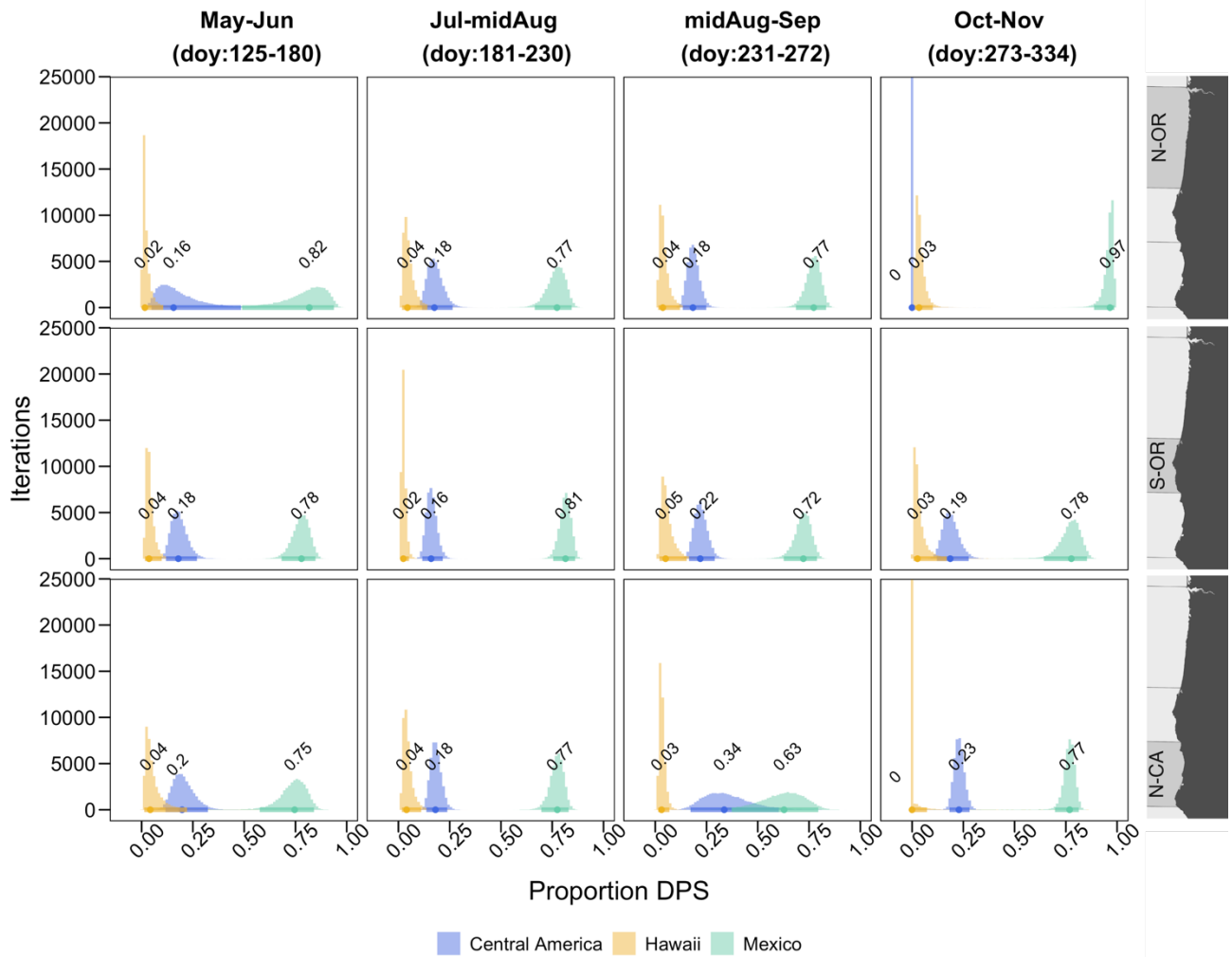


Figure 12: Posterior distributions derived from the hierarchical Bayesian capture-recapture model for the proportion of individual humpback whales belonging to each Distinct Population Segment (DPS) in each zone and time period. Each row represents a different zone (N-OR, S-OR, or N-CA, labeled right), and each column represents a different time period (labeled bottom). Colors represent the three DPS: Central America, Mexico, and Hawaii. The label above each posterior distribution indicates the median, and the horizontal error bars represent the 95% CI.

Table 1: Median, Mean and 95% CI for the proportion of individual humpback whales belonging to each Distinct Population Segment (DPS) in each zone within the study region (N-OR, S-OR, N-CA). Values were estimated by combining the model iterations from all four time periods to provide an estimate of the overall proportion of each DPS present in each zone.

Zone	DPS	Median	Mean	95% CI
N-OR	Mexico	0.80	0.82	0.63-0.98
N-OR	Central America	0.16	0.14	0.00-0.33
N-OR	Hawaii	0.03	0.04	0.01-0.12
S-OR	Mexico	0.78	0.77	0.65-0.85
S-OR	Central America	0.19	0.19	0.12-0.28
S-OR	Hawaii	0.03	0.04	0.01-0.12
N-CA	Mexico	0.75	0.72	0.46-0.83
N-CA	Central	0.22	0.24	0.13-0.50
N-CA	Hawaii	0.03	0.04	0.01-0.13

3. Comparison of site fidelity among DPS

Methods

Due to low and inconsistent effort prior to 2016 (Fig. 11), we only included sightings of individuals between 2016–2024 during the months July–November, to reduce the impact of uneven survey effort on site fidelity results. Site fidelity was calculated for individuals assigned to each DPS (Central America, Mexico and Unknown) using the Standardized Site Fidelity Index (SSFI) developed by Tschopp et al. (2018). SSFI to the entire region (combined zones N-OR, S-OR, and N-CA; Fig. 11) was calculated for (1) all individuals and (2) for all individuals seen on two or more occasions. An occasion was defined based on the same time periods in the capture-recapture model (Jul-midAug, midAug-Sep, Oct-Nov) so that any number of sightings during one time period counted as one occasion. To test for differences in site fidelity to our study region among each of the DPS, we applied the non-parametric Kruskal-Wallis rank test (Kruskal and Wallis, 1952) and post-hoc Dunn tests with Benjamini–Hochberg correction (Benjamini and Hochberg, 2018), using the R package rstatix (Kassambara, 2019).

Results

Between 2016 and 2024, during months July–November, 1,111 individuals were captured. Of these individuals, 271 were captured on two or more occasions. The overall mean SSFI of individuals sighted in the study region (inclusive of N-CA, S-OR, and N-OR) was 0.06 (SD=0.14), and 0.26 (SD=0.16) for individuals captured on two or more occasions.

The mean and median SSFI were similar among all DPS, besides the Unknown category. Calculated SSFI for all individuals, as well as the subset captured on two or more occasions, was lower for Unknown DPS individuals compared to Mexico, Central America, and Hawaii (Table 2). This difference was statistically significant when comparing Unknown DPS individuals to Mexico and Central America DPS individuals ($p < 0.0001$, Kruskal-Wallis test; $p < 0.0001$ for the pairwise comparison between Mexico and Unknown, and between Central America and Unknown using a Dunn test).

Table 2: Estimates of humpback whale site fidelity in the study region based on the Standardized Site Fidelity Index (SSFI; occasions indicate distinct years). N=number of individuals, SD=standard deviation.

Individuals captured on two or more occasions (n=271)				
DPS	Median	Mean	SD	N
Mexico	0.294	0.275	0.154	189
Central America	0.308	0.264	0.160	35
Hawaii	0.294	0.272	0.157	7
Unknown	0.100	0.148	0.163	40
All individuals (n=1111)				
DPS	Median	Mean	SD	N
Mexico	0	0.086	0.154	603
Central America	0	0.079	0.149	117
Hawaii	0	0.068	0.141	28
Unknown	0	0.016	0.071	363

4. Latitudinal changes in sighting distribution: 2016–2024

Methods

To investigate whether DPS units of humpback whales in our study region have changed their latitudinal distribution, we applied Generalized Additive Models (GAMs; Hastie and Tibshirani, 1990) to the 2016–2024 (months July–November) portion of the dataset (when effort was highest and most consistent, Fig. 11). Given the increasing densities of humpback whales in Oregon waters (Derville et al., 2022), we hypothesized that newly recruited individuals would be more likely to be sighted at higher (i.e. more northerly) latitudes. However, since the actual year an individual is recruited into the population (i.e., born or permanently immigrated) is unknown, we used the year an individual was added to the catalog (MinYear) as our main predictor variable of interest.

To determine the effect of MinYear on their sighting latitude, we controlled for the year of the sighting (Year), the amount of effort (Effort), and the identity of the individual, treated as a random factor (ID):

$$g(\text{Latitude}) \sim s(\text{MinYear}) + s(\text{Year}) + s(\text{ID}) + s(\text{Effort})$$

Results

The effect of MinYear was significant for the Mexico and Unknown DPS models ($p=0.007$ and $p=0.005$, respectively; Table 3). Individuals belonging to these DPS (Mexico and Unknown) had higher predicted latitudes (i.e., they were more likely to be sighted further north) at increasing (i.e., more recent) MinYear, up to 2022 (Fig. 13). Individuals added to the catalog during 2022 or later had a slight decreasing trend in their sighting latitudes (Fig. 13).

Table 3: Summary of the outputs for each generalized additive model (GAM) fit to the latitude of sightings of humpback whales in our study region, using data collected between 2016 and 2024. A separate model was fit to individuals assigned to each DPS category: Mexico, Central America, Hawaii, and Unknown. Dev. exp=deviance explained, F=F-statistic, edf=effective degrees of freedom, and P=p-value. P-values with a significance level ≤ 0.05 are shown in bold.

Smooth terms:						
Model	Response	Dev.exp.(%)	MinYear	Year	ID	Effort
Mexico	Latitude	83.90%	F=3.99	F=15.75	F=2.58	F=81.53
			edf=2.91	edf=3.75	edf=319.8	edf=3.71
			P=0.007	P<2e-16	P<2e-16	P<2e-16
Central America	Latitude	89.90%	F=0.17	F=8.43	F=5.24	F=30.88
			edf=1.0	edf=3.44	edf=58.50	edf=2.18
			P=0.69	P=2.44e-5	P<2e-16	P<2e-16
Hawaii	Latitude	58.60%	F=1.54	F=1.00	F=0.01	F=0.61
			edf=1.7	edf=1.00	edf=1.0	edf=3.57
			P=0.22	P=0.18	P=0.43	P=0.001
Unknown	Latitude	95.90%	F=3.82	F=13.29	F=3.86	F=50.25
			edf=3.0	edf=3.90	edf=285.3	edf=3.38
			P=0.005	P<2e-16	P<2e-16	P<2e-16

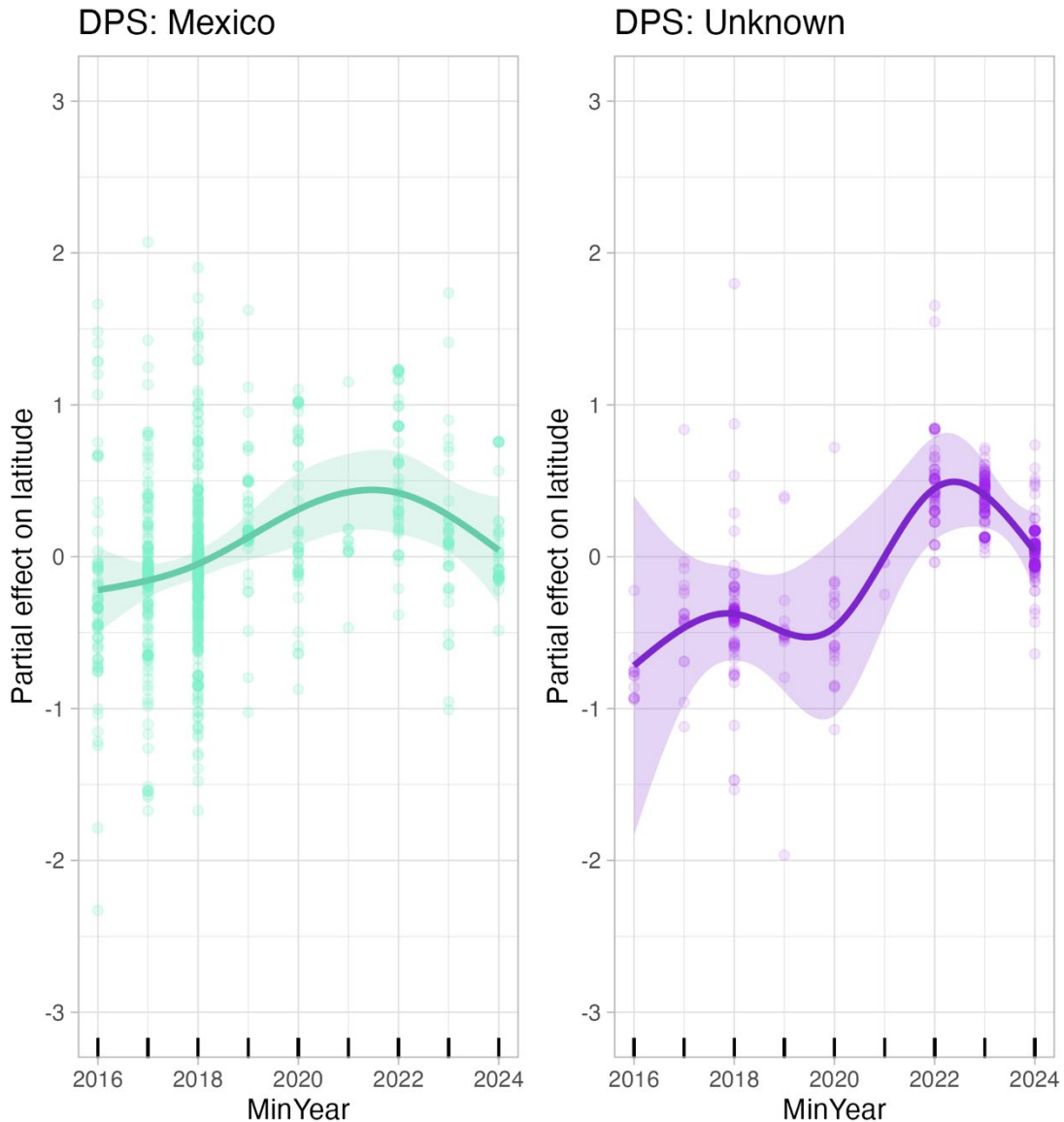


Figure 13: Partial effect of the year an individual humpback whale was added to the photo-ID catalog (*MinYear*) on the latitude of sightings for the Mexico DPS (green) and for Unknown DPS (purple). Each line represents the mean predicted effect of *MinYear*, and the ribbon represents the 95% CI of the effect. Lightly colored points represent the residuals from the data.

Explanation of any problems or delays in accomplishing planned activities:

As mentioned in Steps 13 and 14, fish layers will not be available from ERRDAP going forward, forcing SDM predictions of whale distribution used in the R shiny app to be based on abiotic or krill layers only. We are assessing how model predictions of fisheries overlap will be affected by this issue, which will inform next steps in R shiny development.

Logbook data for fixed gear groundfish fisheries has proven challenging and taken longer to process and develop estimation procedures for due to the multi-species, multi-gear nature of the data.

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