Biologically Important Areas II for cetaceans within U.S. and adjacent waters – West Coast Region

Supplementary File B: BIA Supplementary Descriptions and Scores

John Calambokidis[1], Michaela A. Kratofil[1], Daniel M. Palacios[2,3], Barbara A. Lagerquist[2,3], Gregory S. Schorr[4], M. Bradley Hanson[5], Robin W. Baird[1], Karin A. Forney[6], Elizabeth A. Becker[7], R. Cotton Rockwood[8], Elliott L. Hazen[9]*

[1]Cascadia Research Collective, Olympia, WA, USA
[2]Marine Mammal Institute, Oregon State University, Newport, OR, USA
[3]Department of Fisheries, Wildlife, and Conservation Sciences, Oregon State University, Corvallis, OR, USA
[4]Marine Ecology and Telemetry Research, Seabeck, WA, USA
[5]National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA
[6]National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center, Moss Landing, CA
[7]Ocean Associates, Inc., under contract to the Marine Mammal and Turtle Division, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, La Jolla, CA
[8]Point Blue Conservation Science, Petaluma, CA, USA
[9]National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center, Monterey, CA

*__Correspondence:__
John Calambokidis
calambokidis@cascadiaresearch.org

7. Biologically Important Areas for Cetaceans Within U.S. Waters – West Coast Region

Supplementary Descriptions

BIAs are sorted by species common name, BIA type, Importance Score and descriptive name. Child BIAs, if present, follow the parent BIA in the order of Importance Score and descriptive name.

Supplementary Description 7. 1. Blue whale feeding area

Species name: Blue whale (*Balaenoptera musculus*)

Stock or population: Eastern North Pacific

Descriptive name: Blue whale West Coast - Parent

BIA type: Feeding Area

BIA label: F-BIA2-s-b3-WC032-0a

Transboundary across: None

Hierarchy: Hierarchical BIA; Parent of children a

Importance score: 2 (Intensity: 2, Data support: 3)

Supporting notes for intensity score: We assigned an Intensity score of 2 for this BIA due to the following reasons:

- Blue whales make extensive movements from low-latitude breeding grounds off Central America to productive, high-latitude feeding grounds off the US West Coast, with most feeding blue whales concentrated off the California coast, as described by this revised BIA.
- The total abundance estimate for blue whales in the eastern North Pacific was recently estimated at 1,898 (SE=161) individuals (Calambokidis and Barlow, 2020), with a slight positive population growth trend since the 1990s.
- Blue whales can be found off the US West Coast throughout the year although concentrations begin to increase in late spring, peak in the summer and fall, and decrease in the late fall into winter. This seasonal occurrence aligns with seasonal prey availability along the US West Coast and the feeding BIA described here captures the early summer to late fall period (June through November).
- HD model predicted density threshold value chosen for the BIA boundary determination process includes highest whale densities predicted for the study area, and the greatest proportion of overlapping blue whale HRs out of 110 total HRs.
- No other feeding BIA is being delineated for eastern North Pacific blue whales, highlighting the importance of the BIA described here for the entire eastern North Pacific blue whale population

Supporting notes for data support score: We assigned a Data Support score of 3 for this BIA based on the following lines of supporting evidence:

- These revised feeding BIA boundaries and corresponding time period were informed by additional sightings obtained since the initial 2015 effort, spanning 34 years in total (1986-2020), and restricted to sightings where feeding or milling behaviors were observed.
- The addition of home ranges derived from 110 satellite tagged blue whales since 1998 provided a more unbiased (relative to dedicated survey efforts) perspective on the distribution of these whales feeding off the US West Coast. Satellite tag locations used to derive feeding home ranges were informed by movement model estimated behaviors (i.e., area-restricted search; Irvine et al., 2014; Mate et al., 2018) and only included data from tags that transmitted at least 30 days of data.
- Although nearly half of the satellite tags included in this assessment were deployed off the southern California coast, individuals tagged here generally remained within the stretch of the coast from the Gulf of Farallones to the Channel Islands further supporting site importance of this region as a feeding ground for blue whales; these grounds are highlighted by the child (core) BIA.
- Habitat-based density models used represent multi-year averages (spanning 1991-2018) of predictions during the summer/fall feeding season reflecting a broader distribution for the BIAs, and account for potential range shifts related to variations in decadal oceanographic conditions over the study period (Becker et al., 2020b; Calambokidis et al., 2009). Predicted densities agree with concentrations of both sightings of feeding/milling blue whales and overlap of individual feeding blue whale home ranges derived from satellite tag data.
- Abundance estimates specific to this population in the eastern North Pacific are contemporary and based on long-term sighting and photographic data (Calambokidis and Barlow, 2020).
- Child (core) BIA highlights feeding “hotspots” within the broader parent BIA boundary agreed among higher levels of each supporting data layer (concentrations of sightings, increased home range overlap from satellite tagged whales, higher habitat-based density model predictions).

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Spatiotemporal variability indicator for both parent and core blue whale F-BIAs is static. Blue whales may respond to spatiotemporal variation in the environment and some of the habitat models for large whales have incorporated dynamic variables to try and predict this (Forney et al. 2012, Becker et al 2020a. 2020b, Abrahms et al. 2019a, 2019b). More specifically, common variation in oceanographic conditions along the West Coast region often results in variation in the spatial distribution of large whale prey patches (e.g., krill, anchovies). As such, these whales may adjust their feeding behavior in space and time accordingly. However, we assigned a Spatiotemporal Variability Indicator score of “static” for all BIAs here, due to the following reasons: (1) for BIAs derived from the integrated approach (such as this one), we intentionally attempted to account for year-to-year variability in whale distribution by using multi-year averaged HD model outputs; (2) many of the BIAs' spatial extents cover large areas, such that whale distribution within those areas may change in response to the environment, but the spatial polygons themselves are unlikely to move in space or time.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainty for both the parent and child blue whale feeding BIAs described in this assessment, although see narrative on spatiotemporal variability above. This boundary is supported by three independent data sources (sightings from small-boat surveys, home ranges from long-term satellite tag deployments, multi-year averaged habitat-based density models) and combined have complementary strengths and weaknesses. The parent BIA boundary characterized here encompasses (1) nearly all visual sightings of feeding or milling blue whales documented from 1986 through 2020; (2) a large proportion of shared home ranges from satellite tagged blue whales; and (3) broad levels of predicted densities from HD models along the coastline. The resulting child BIA reflects higher intensity values of all three supporting data layers, highlighting known (e.g., Channel Islands, Gulf of Farallones) important primary feeding grounds for blue whales within the broader coast-wide West Coast feeding ground.

Months of year designation is applicable: June, July, August, September, October, November

Tagging data supporting designation (Y/N): Y

# of tags: 110

# of years in which supporting tagging data collected: 12 (1998-2017)

Supporting information: Feeding home ranges (HR) were estimated for 110 blue whales satellite-tagged by OSU off California from 1998 through 2017 (Irvine et al. 2014; Mate et al. 2018). HRs were estimated for individual tagged whales using kernel density estimation methods as described in Irvine et al. (2014) and Mate et al. (2018); details on satellite tag data processing methods are provided as supplementary material. We quantified intensity of space use by mapping each individual's home range on a 10 km x 10 km raster (all on the same grid), summing the total number of home ranges in each cell across all individuals, and calculating the proportion of the total 110 home ranges within each grid cell. For the parent BIA, we chose a proportion of all home ranges based on a threshold value of 0.082 (i.e., grid cells with greater than 0.082 proportion of all home ranges included). For the core BIA, a threshold value of 0.155 proportion of the total 110 home ranges was chosen.

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 4,395

# of years in which supporting visual data collected: 34 (1986-2020)

Supporting information: Sightings data used for the BIA boundary determinations were collected from dedicated small boat survey efforts conducted by CRC from 1986 through 2020; only sightings where feeding or milling behaviors were observed were included in this assessment (n=4,395). To create a layer based on this dataset, we used kernel density estimation (KDE) to generate a two-dimensional probability distribution using the package ks (Duong, 2021). The bandwidth value (smoothing parameter) was set to 10 kilometers. For the parent BIA, a broad KDE contour threshold of at least 90% was chosen. For the core BIA, a narrower threshold of 80% was chosen.

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): Y

Supporting information: Calambokidis et al., 1990, 2009

Genetic analyses conducted supporting designation (Y/N): N

What factors justify the boundary selection?: A combination of sightings data collected from dedicated small boat survey efforts by Cascadia Research Collective (CRC), satellite tag data from long-term implant tags deployed by Oregon State University (OSU), and multi-year averaged habitat-based density (HD) models generated by Southwest Fisheries Science Center (SWFSC) were used to inform BIA boundaries for blue whale feeding BIAs off the US West Coast. For each of the three datasets, two threshold values were chosen: one for creating parent BIAs (i.e., broader distribution) and one for creating child BIAs to represent core areas of use (core BIA, hereafter). Spatial filters were applied to restrict each dataset to the subset of area which met the density or habitat use thresholds. For each of the three data layers (tag HRs, HD model, sightings KDE), there is variability in values across species (or populations): (1) variability in density values across species (or populations) that relates to factors such as the geographic range of the species, behavior of the species, relative abundance, and survey coverage (or sample size of whales tagged); and (2) variability in the spatial sampling across the three data layers, due to the nature of the "survey" methods underlying each layer (i.e., large-scale ship-based line-transect surveys, free movements of tagged whales, localized small-boat surveys). Because of (1), setting exact, quantitative density values for each of the three layers for all species (e.g., 0.005 whales/km2 predicted density for all) would not result in species-specific biologically important areas. While equal quantile-based thresholds could be established across layers to mitigate this (e.g., 0.60 quantile for all data layers), this approach would fail to recognize substantial differences in the spatial scale that each layer reflects (i.e., variation from (2)). Therefore, in attempt to recognize biases that could arise from both (1) and (2) while also maintaining consistency across large whale F-BIAs, we applied a general approach in which threshold values for parent and child BIAs were defined by quantiles specific to each data layer but held the same across species. Layer-specific quantile-based threshold values were justified through expert elicitation (see manuscript for full explanation. The parent BIA HD model layer threshold was specified as the 0.80 quantile, and the core BIA threshold was one quantile higher than the parent BIA threshold (0.90 quantile) for all species. The parent BIA tagged whale home range (HR) threshold was specified as the 0.20 quantile of the total proportion of overlapping HRs and the core BIA threshold value was the 0.30 quantile of the total range of overlapping HRs. Quantiles of the proportion of overlapping HRs were the same across species. For the parent BIAs, the 90% sightings KDE contour was used and for the core BIAs, one intensity level higher (80% sightings KDE contour) was used.

All analyses were conducted within the program R (R Core Team, 2021). The inner (shoreward) boundary of the parent BIA was defined as the 50 m depth contour and the child (core) BIA was defined as the 80 m depth contour, based on the depth frequency of small boat sightings (see supplementary materials for figures). Our intention with these inner boundary definitions was to capture the nearshore nature of this species while recognizing that to some degree their densities decrease with increased distance to shore.

Each of the three data layers relies on different datasets that have their own strengths and weaknesses. The sighting database is based on more than 4,000 observations of blue whales feeding or milling but is biased by the uneven distribution of effort. The tagging data includes 110 deployments with tagging locality bias in southern California but provide detailed patterns of movement over extensive periods, and the habitat-density model is based on sightings from ship-board line-transect surveys covering the entire West Coast including offshore waters, but is limited to sightings collected during these surveys which were conducted only every few years. Integrating these three datasets and looking at areas of agreement (overlap) provides the most comprehensive way to set BIAs, taking into consideration the potential strengths and biases of each dataset.

Habitat-based density model supporting information:

Multi-year averaged HD model predictions based on data collected from surveys from 1991 to 2018 were used in the BIA boundary determinations; details on survey design and HD modeling methods are described in Becker et al. (2020a, 2020b). The more recent predictions reported in Becker et al. (2020b) do not extend to the Washington US/Canada border. However, earlier HD predictions reported by Becker et al. (2020a) do extend to this northern region, albeit based on lower survey effort (1991-2014), and therefore, the northern portion of predictions from Becker et al. (2020a) were extracted and merged with the Becker et al. (2020b) predictions to create a more complete HD model layer for humpback whales along the U.S. west coast. The parent BIA threshold was 0.00093 whales/km2 and the core BIA threshold was 0.0018 whales/km2.

Data sources: Oregon State University (accessed 2021); Cascadia Research Collective (accessed 2021); Southwest Fisheries Science Center, National Marine Fisheries Service (accessed 2021)

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 1

References: Becker, E.A., K. Forney, P. Fiedler, J. Barlow, S. Chivers, C.A. Edwards, A.M. Moore, and J.V. Redfern. 2016. Moving towards dynamic ocean management: How well do modeled ocean products predict species distributions? Remote Sensing 8:149-226

Becker, E.A., J.V. Caretta, K.A. Forney, J. Barlow, S. Brodie, R. Hoopes, J.G. Jacox, S.M. Maxwell, J.V. Redfern, N.B. Sisson, H. Welch, and E.L. Hazen. 2020a. Performance evaluation of cetacean species distribution models developed using generalized additive models and boosted regression trees. Ecology and Evolution 10:5759-5784 doi:10.1001/ece3.6316

Becker, E.A., K.A. Forney, D.L. Miller, P.C. Fidler, J. Barlow, and J.E. Moore. 2020b. Habitat-based density estimates for cetaceans in the California Current Ecosystem based on 1991-2018 survey data. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-638.

Calambokidis J, Barlow J (2004) Abundance of blue and humpback whales in the eastern North Pacific estimated by capture-recapture and line-transect methods. Marine Mammal Science 20(1):63-85.

Calambokidis J, Barlow J (2013) Updated abundance estimates of blue and humpback whales off the US West Coast incorporating photo-identifications from 2010 and 2011. Final Report for contract AB-133F-10-RP-0106. PSRG-2013-13R. 8pp.

Calambokidis, J., and J. Barlow. 2020. Abundance estimates for blue and humpback whales along the U.S. West Coast using data through 2018. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-634.

Calambokidis J, Steiger GH, Cubbage JC, Balcomb KC, Ewald C, Kruse S et al. (1990) Sightings and movements of blue whales off central California 1986 88 from photo identification of individuals. Report of the International Whaling Commission (special issue 12):343 348.

Calambokidis, J., J. Barlow, J.K.B. Ford, T.E. Chandler, and A.B. Douglas. 2009. Insights into the population structure of blue whales in the eastern North Pacific from recent sightings and photographic identifications. Marine Mammal Science 25:816-832.

Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Calambokidis, J., J.A. Fahlbusch, A.R. Szesciorka, B.L. Southall, D.E. Cade, A.S. Friedlaender, and J.A. Goldbogen. 2019. Differential Vulnerability to Ship Strikes between Day and Night for Blue, Fin, and Humpback Whales Based on Dive and Movement Data from Medium Duration Archival Tags. Frontiers in Marine Science, 6 Article 543. doi.org/10.3389/fmars.2019.00543

Duong, T. 2021. Ks: Kernel Smooth. R package version 1.13.2. https://CRAN.R-project.org/package=ks

Hazen, E.L., D.M. Palacios, K.A. Forney, E.A. Howell, E. Becker, A.L. Hoover, L. Irvine, M. DeAngelis, S.J. Bograd, B.R. Mate, and H. Bailey. 2017. WhaleWatch: A dynamic management tool for predicting blue whale density in the California Current. Journal of Applied Ecology 54(5):1415-1428

Irvine, L.M., B.R. Mate, M.H. Winsor, D.M. Palacios, S.J. Bograd, D.P. Costa, and H. Bailey. 2014. Spatial and temporal occurrence of blue whales off the U.S. West Coast, with implications for management. PLoS ONE 9(7): e102959. Doi: 10.1371/journal.pone.0102959

Mate, B.R., D.M. Palacios, C.S. Baker, B.A. Lagerquist, L.M. Irvine, T. Follett, D. Steel, C.E. Hayslip, and M.H. Winsor. 2018. Baleen whale tagging in support of marine mammal monitoring across multiple navy training areas covering the years 2014, 2015, 2016, and 2017. Final Report. Prepared for Commander, U.S. Pacific Fleet. Submitted to Naval Facilities Engineering Command Southwest under Contract No. N62470-15-8006-17F4016 issued to HDR Inc., San Diego, California. October 2018

Palacios, D.M., H. Bailey, E.A. Becker, S.J. Bograd, M.L. DeAngelis, K.A. Forney, E.L. Hazen, L.M. Irvine, and B.R. Mate. 2019. Ecological correlates of blue whale movement behavior and its predictability in the California Current Ecosystem during the summer-fall feeding season. Movement Ecology 7:26

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria https://www.R-project.org/

Redfern, J.V., M.F. McKenna, T.J. Moore, J. Calambokidis, M.L. DeAngelis, E.A. Becker, J. Barlow, K.A. Forney, P.C. Fiedler, and S.J. Chivers. 2013. Assessing the risk of ships striking large whales in marine spatial planning. Conservation Biology 27:2925-302.

Rockwood, R.C., J. Calambokidis, J. Jahncke. 2017. High mortality of blue, humpback and fin whales from modeling of vessel collisions on the U.S. West Coast suggests population impacts and insufficient protection. PloS ONE 12(8): e0183052. https://doi.org/10.1371/journal.pone.0183052

from 1982-2017. NOAA Tech. Memo. NMFS-OPR-63A, 50 p.

Schorr, G., E. Falcone, and C. Calambokidis. 2013. Summary of tag deployments on cetaceans off Washington, May 2010 to May 2013. Prepared for Commander, U.S. Pacific Fleet, Pearl Harbor, Hawaii. Submitted to Naval Facilities Engineering Command Pacific (NAVFAC PAC), Pearl Harbor, Hawaii 96860-3134, and Naval Facilities Engineering Command Northwest (NAVFAC NW), Silverdale, WA 98315-1101, under Contract # N62470-10-D-3011, issued to HDR Inc., San Diego, California 92123. 12 June 2013.

Supplementary Description 7. 2. Blue whale feeding area

Species name: Blue whale (*Balaenoptera musculus*)

Stock or population: Eastern North Pacific

Descriptive name: Blue whale West Coast - Core

BIA type: Feeding Area

BIA label: F-BIA3-s-b3-WC032-a

Transboundary across: None

Hierarchy: Hierarchical BIA; Child a

Importance score: 3 (Intensity: 3, Data support: 3)

Supporting notes for intensity score: We assigned an Intensity score of 3 for this BIA due to the following reasons:

• Blue whales make extensive movements from low-latitude breeding grounds off Central America to productive, high-latitude feeding grounds off the US West Coast, with most feeding blue whales concentrated off the California coast, as described by this revised BIA.

• The total abundance estimate for blue whales in the eastern North Pacific was recently estimated at 1,898 (SE=161) individuals (Calambokidis and Barlow, 2020), with a slight positive population growth trend since the 1990s.

• Blue whales can be found off the US West Coast throughout the year although concentrations begin to increase in late spring, peak in the summer and fall, and decrease in the late fall into winter. This seasonal occurrence aligns with seasonal prey availability along the US West Coast and the feeding BIA described here captures the early summer to late fall period (June through November).

• HD model predicted density threshold value chosen for the BIA boundary determination process includes highest whale densities predicted for the study area, and the greatest proportion of overlapping blue whale HRs out of 110 total HRs.

• No other feeding BIA is being delineated for eastern North Pacific blue whales, highlighting the importance of the BIA described here for the entire eastern North Pacific blue whale population

Supporting notes for data support score: We assigned a Data Support score of 3 for this BIA based on the following lines of supporting evidence:

• These revised feeding BIA boundaries and corresponding time period were informed by additional sightings obtained since the initial 2015 effort, spanning 34 years in total (1986-2020), and restricted to sightings where feeding or milling behaviors were observed.

• The addition of home ranges derived from 110 satellite tagged blue whales since 1998 provided a more unbiased (relative to dedicated survey efforts) perspective on the distribution of these whales feeding off the US West Coast. Satellite tag locations used to derive feeding home ranges were informed by movement model estimated behaviors (i.e., area-restricted search; Irvine et al., 2014; Mate et al., 2018) and only included data from tags that transmitted at least 30 days of data.

• Although nearly half of the satellite tags included in this assessment were deployed off the southern California coast, individuals tagged here generally remained within the stretch of the coast from the Gulf of Farallones to the Channel Islands further supporting site importance of this region as a feeding ground for blue whales; these grounds are highlighted by the child (core) BIA.

• Habitat-based density models used represent multi-year averages (spanning 1991-2018) of predictions during the summer/fall feeding season reflecting a broader distribution for the BIAs, and account for potential range shifts related to variations in decadal oceanographic conditions over the study period (Becker et al., 2020b; Calambokidis et al., 2009). Predicted densities agree with concentrations of both sightings of feeding/milling blue whales and overlap of individual feeding blue whale home ranges derived from satellite tag data.

• Abundance estimates specific to this population in the eastern North Pacific are contemporary and based on long-term sighting and photographic data (Calambokidis and Barlow, 2020).

• Child (core) BIA highlights feeding "hotspots" within the broader parent BIA boundary agreed among higher levels of each supporting data layer (concentrations of sightings, increased home range overlap from satellite tagged whales, higher habitat-based density model predictions).

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Spatiotemporal variability indicator for both parent and core blue whale F-BIAs is static. Blue whales may respond to spatiotemporal variation in the environment and some of the habitat models for large whales have incorporated dynamic variables to try and predict this (Forney et al. 2012, Becker et al 2020a. 2020b, Abrahms et al. 2019a, 2019b). More specifically, common variation in oceanographic conditions along the West Coast region often results in variation in the spatial distribution of large whale prey patches (e.g., krill, anchovies). As such, these whales may adjust their feeding behavior in space and time accordingly. However, we assigned a Spatiotemporal Variability Indicator score of "static" for all BIAs here, due to the following reasons: (1) for BIAs derived from the integrated approach (such as this one), we intentionally attempted to account for year-to-year variability in whale distribution by using multi-year averaged HD model outputs; (2) many of the BIAs' spatial extents cover large areas, such that whale distribution within those areas may change in response to the environment, but the spatial polygons themselves are unlikely to move in space or time.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainty for both the parent and child blue whale feeding BIAs described in this assessment, although see narrative on spatiotemporal variability above. This boundary is supported by three independent data sources (sightings from small-boat surveys, home ranges from long-term satellite tag deployments, multi-year averaged habitat-based density models) and combined have complementary strengths and weaknesses. The parent BIA boundary characterized here encompasses (1) nearly all visual sightings of feeding or milling blue whales documented from 1986 through 2020; (2) a large proportion of shared home ranges from satellite tagged blue whales; and (3) broad levels of predicted densities from HD models along the coastline. The resulting child BIA reflects higher intensity values of all three supporting data layers, highlighting known (e.g., Channel Islands, Gulf of Farallones) important primary feeding grounds for blue whales within the broader coast-wide West Coast feeding ground.

Months of year designation is applicable: June, July, August, September, October, November

Tagging data supporting designation (Y/N): Y

# of tags: 110

# of years in which supporting tagging data collected: 12 (1998-2017)

Supporting information: Feeding home ranges (HR) were estimated for 110 blue whales satellite-tagged by OSU off California from 1998 through 2017 (Irvine et al. 2014; Mate et al. 2018). HRs were estimated for individual tagged whales using kernel density estimation methods as described in Irvine et al. (2014) and Mate et al. (2018); details on satellite tag data processing methods are provided as supplementary material. We quantified intensity of space use by mapping each individual's home range on a 10 km x 10 km raster (all on the same grid), summing the total number of home ranges in each cell across all individuals, and calculating the proportion of the total 110 home ranges within each grid cell. For the parent BIA, we chose a proportion of all home ranges based on a threshold value of 0.082 (i.e., grid cells with greater than 0.082 proportion of all home ranges included). For the core BIA, a threshold value of 0.155 proportion of the total 110 home ranges was chosen.

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 4,395

# of years in which supporting visual data collected: 34 (1986-2020)

Supporting information: Sightings data used for the BIA boundary determinations were collected from dedicated small boat survey efforts conducted by CRC from 1986 through 2020; only sightings where feeding or milling behaviors were observed were included in this assessment (n=4,395). To create a layer based on this dataset, we used kernel density estimation (KDE) to generate a two-dimensional probability distribution using the package ks (Duong, 2021). The bandwidth value (smoothing parameter) was set to 10 kilometers. For the parent BIA, a broad KDE contour threshold of at least 90% was chosen. For the core BIA, a narrower threshold of 80% was chosen.

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): Y

Supporting information: Calambokidis et al., 1990, 2009

Genetic analyses conducted supporting designation (Y/N): N

What factors justify the boundary selection?: A combination of sightings data collected from dedicated small boat survey efforts by Cascadia Research Collective (CRC), satellite tag data from long-term implant tags deployed by Oregon State University (OSU), and multi-year averaged habitat-based density (HD) models generated by Southwest Fisheries Science Center (SWFSC) were used to inform BIA boundaries for blue whale feeding BIAs off the US West Coast. For each of the three datasets, two threshold values were chosen: one for creating parent BIAs (i.e., broader distribution) and one for creating child BIAs to represent core areas of use (core BIA, hereafter). Spatial filters were applied to restrict each dataset to the subset of area which met the density or habitat use thresholds. For each of the three data layers (tag HRs, HD model, sightings KDE), there is variability in values across species (or populations): (1) variability in density values across species (or populations) that relates to factors such as the geographic range of the species, behavior of the species, relative abundance, and survey coverage (or sample size of whales tagged); and (2) variability in the spatial sampling across the three data layers, due to the nature of the "survey" methods underlying each layer (i.e., large-scale ship-based line-transect surveys, free movements of tagged whales, localized small-boat surveys). Because of (1), setting exact, quantitative density values for each of the three layers for all species (e.g., 0.005 whales/km2 predicted density for all) would not result in species-specific biologically important areas. While equal quantile-based thresholds could be established across layers to mitigate this (e.g., 0.60 quantile for all data layers), this approach would fail to recognize substantial differences in the spatial scale that each layer reflects (i.e., variation from (2)). Therefore, in attempt to recognize biases that could arise from both (1) and (2) while also maintaining consistency across large whale F-BIAs, we applied a general approach in which threshold values for parent and child BIAs were defined by quantiles specific to each data layer but held the same across species. Layer-specific quantile-based threshold values were justified through expert elicitation (see manuscript for full explanation. The parent BIA HD model layer threshold was specified as the 0.80 quantile, and the core BIA threshold was one quantile higher than the parent BIA threshold (0.90 quantile) for all species. The parent BIA tagged whale home range (HR) threshold was specified as the 0.20 quantile of the total proportion of overlapping HRs and the core BIA threshold value was the 0.30 quantile of the total range of overlapping HRs. Quantiles of the proportion of overlapping HRs were the same across species. For the parent BIAs, the 90% sightings KDE contour was used and for the core BIAs, one intensity level higher (80% sightings KDE contour) was used.

All analyses were conducted within the program R (R Core Team, 2021). The inner (shoreward) boundary of the parent BIA was defined as the 50 m depth contour and the child (core) BIA was defined as the 80 m depth contour, based on the depth frequency of small boat sightings (see supplementary materials for figures). Our intention with these inner boundary definitions was to capture the nearshore nature of this species while recognizing that to some degree their densities decrease with increased distance to shore.

Each of the three data layers relies on different datasets that have their own strengths and weaknesses. The sighting database is based on more than 4,000 observations of blue whales feeding or milling but is biased by the uneven distribution of effort. The tagging data includes 110 deployments with tagging locality bias in southern California but provide detailed patterns of movement over extensive periods, and the habitat-density model is based on sightings from ship-board line-transect surveys covering the entire West Coast including offshore waters, but is limited to sightings collected during these surveys which were conducted only every few years. Integrating these three datasets and looking at areas of agreement (overlap) provides the most comprehensive way to set

BIAs, taking into consideration the potential strengths and biases of each dataset.

Habitat-based density model supporting information:

Multi-year averaged HD model predictions based on data collected from surveys from 1991 to 2018 were used in the BIA boundary determinations; details on survey design and HD modeling methods are described in Becker et al. (2020a, 2020b). The more recent predictions reported in Becker et al. (2020b) do not extend to the Washington US/Canada border. However, earlier HD predictions reported by Becker et al. (2020a) do extend to this northern region, albeit based on lower survey effort (1991-2014), and therefore, the northern portion of predictions from Becker et al. (2020a) were extracted and merged with the Becker et al. (2020b) predictions to create a more complete HD model layer for humpback whales along the U.S. west coast. The parent BIA threshold was 0.00093 whales/km2 and the core BIA threshold was 0.0018 whales/km2.

Data sources: Oregon State University (accessed 2021); Cascadia Research Collective (accessed 2021); Southwest Fisheries Science Center, National Marine Fisheries Service (accessed 2021).

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 1

References: Becker, E.A., K. Forney, P. Fiedler, J. Barlow, S. Chivers, C.A. Edwards, A.M. Moore, and J.V. Redfern. 2016. Moving towards dynamic ocean management: How well do modeled ocean products predict species distributions? Remote Sensing 8:149-226

Becker, E.A., J.V. Caretta, K.A. Forney, J. Barlow, S. Brodie, R. Hoopes, J.G. Jacox, S.M. Maxwell, J.V. Redfern, N.B. Sisson, H. Welch, and E.L. Hazen. 2020a. Performance evaluation of cetacean species distribution models developed using generalized additive models and boosted regression trees. Ecology and Evolution 10:5759-5784 doi:10.1001/ece3.6316

Becker, E.A., K.A. Forney, D.L. Miller, P.C. Fidler, J. Barlow, and J.E. Moore. 2020b. Habitat-based density estimates for cetaceans in the California Current Ecosystem based on 1991-2018 survey data. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-638.
Calambokidis J, Barlow J (2004) Abundance of blue and humpback whales in the eastern North Pacific estimated by capture-recapture and line-transect methods. Marine Mammal Science 20(1):63-85.

Calambokidis J, Barlow J (2013) Updated abundance estimates of blue and humpback whales off the US West Coast incorporating photo-identifications from 2010 and 2011. Final Report for contract AB-133F-10-RP-0106. PSRG-2013-13R. 8pp.

Calambokidis, J., and J. Barlow. 2020. Abundance estimates for blue and humpback whales along the U.S. West Coast using data through 2018. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-634.

Calambokidis J, Steiger GH, Cubbage JC, Balcomb KC, Ewald C, Kruse S et al. (1990) Sightings and movements of blue whales off central California 1986 88 from photo identification of individuals. Report of the International Whaling Commission (special issue 12):343 348.
Calambokidis, J., J. Barlow, J.K.B. Ford, T.E. Chandler, and A.B. Douglas. 2009. Insights into the population structure of blue whales in the eastern North Pacific from recent sightings and photographic identifications. Marine Mammal Science 25:816-832.

Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Calambokidis, J., J.A. Fahlbusch, A.R. Szesciorka, B.L. Southall, D.E. Cade, A.S. Friedlaender, and J.A. Goldbogen. 2019. Differential Vulnerability to Ship Strikes between Day and Night for Blue, Fin, and Humpback Whales Based on Dive and Movement Data from Medium Duration Archival Tags. Frontiers in Marine Science, 6 Article 543. doi.org/10.3389/fmars.2019.00543

Duong, T. 2021. Ks: Kernel Smooth. R package version 1.13.2. https://CRAN.R-project.org/package=ks

Hazen, E.L., D.M. Palacios, K.A. Forney, E.A. Howell, E. Becker, A.L. Hoover, L. Irvine, M. DeAngelis, S.J. Bograd, B.R. Mate, and H. Bailey. 2017. WhaleWatch: A dynamic management tool for predicting blue whale density in the California Current. Journal of Applied Ecology 54(5):1415-1428

Irvine, L.M., B.R. Mate, M.H. Winsor, D.M. Palacios, S.J. Bograd, D.P. Costa, and H. Bailey. 2014. Spatial and temporal occurrence of blue whales off the U.S. West Coast, with implications for management. PLoS ONE 9(7): e102959. Doi: 10.1371/journal.pone.0102959

Mate, B.R., D.M. Palacios, C.S. Baker, B.A. Lagerquist, L.M. Irvine, T. Follett, D. Steel, C.E. Hayslip, and M.H. Winsor. 2018. Baleen whale tagging in support of marine mammal monitoring across multiple navy training areas covering the years 2014, 2015, 2016, and 2017. Final Report. Prepared for Commander, U.S. Pacific Fleet. Submitted to Naval Facilities Engineering Command Southwest under Contract No. N62470-15-8006-17F4016 issued to HDR Inc., San Diego, California. October 2018

Palacios, D.M., H. Bailey, E.A. Becker, S.J. Bograd, M.L. DeAngelis, K.A. Forney, E.L. Hazen, L.M. Irvine, and B.R. Mate. 2019. Ecological correlates of blue whale movement behavior and its predictability in the California Current Ecosystem during the summer-fall feeding season. Movement Ecology 7:26

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria https://www.R-project.org/

Redfern, J.V., M.F. McKenna, T.J. Moore, J. Calambokidis, M.L. DeAngelis, E.A. Becker, J. Barlow, K.A. Forney, P.C. Fiedler, and S.J. Chivers. 2013. Assessing the risk of ships striking large whales in marine spatial planning. Conservation Biology 27:2925-302.

Rockwood, R.C., J. Calambokidis, J. Jahncke. 2017. High mortality of blue, humpback and fin whales from modeling of vessel collisions on the U.S. West Coast suggests population impacts and insufficient protection. PloS ONE 12(8): e0183052. https://doi.org/10.1371/journal.pone.0183052

Saez L, Lawson D, and DeAngelis M. 2021. Large whale entanglements off the U.S. West Coast, from 1982-2017. NOAA Tech. Memo. NMFS-OPR-63A, 50 p.

Schorr, G., E. Falcone, and C. Calambokidis. 2013. Summary of tag deployments on cetaceans off Washington, May 2010 to May 2013. Prepared for Commander, U.S. Pacific Fleet, Pearl Harbor, Hawaii. Submitted to Naval Facilities Engineering Command Pacific (NAVFAC PAC), Pearl Harbor, Hawaii 96860-3134, and Naval Facilities Engineering Command Northwest (NAVFAC NW), Silverdale, WA 98315-1101, under Contract # N62470-10-D-3011, issued to HDR Inc., San Diego, California 92123. 12 June 2013.

Supplementary Description 7. 3. Fin whale feeding area

Species name: Fin whale (*Balaenoptera physalus*)

Descriptive name: Fin whale West Coast - Parent

BIA type: Feeding Area

BIA label: F-BIA1-s-b2-WC033-0a

Transboundary across: None

Hierarchy: Hierarchical BIA; Parent of children a

Importance score: 1 (Intensity: 1, Data support: 2)

Supporting notes for intensity score: We assigned an Intensity score of 1 for this BIA due to the following reasons:

- Fin whales make migratory movements along the US West Coast to reach productive, high latitude feeding grounds; however previous studies have indicated that not all fin whales undertake seasonal migrations (e.g., Falcone and Schorr, 2013)
- The total abundance estimate for fin whales was recently estimated at 11,065 (CV=0.405) individuals (Becker et al., 2020b), based on species distribution models generated from 1991-2018 line-transect survey data (abundance estimate for 2018 year).
- Fin whales can be found off the US West Coast throughout the year although feeding aggregations begin to increase in late spring, peak in the summer and fall, and decrease in the late fall into winter. This seasonal occurrence aligns with seasonal prey availability along the US West Coast and the feeding BIA described here captures the early summer to late fall period (June through November).
- One other feeding BIA is being delineated for fin whales in the eastern North Pacific (Bering Sea)
- Both parent and core BIAs cover broad areas in this region that extend to all fin whales occurring along the West Coast

Supporting notes for data support score: We assigned a Data Support score of 2 for this BIA based on the following lines of supporting evidence:

- These new feeding BIA boundaries and corresponding time period were informed by a combination of sightings spanning 34 years in total (1986-2020) and restricted to sightings where feeding or milling behaviors were observed.
- The addition of home ranges derived from 79 satellite tagged fin whales since 2006 during 11 unique years provided a more unbiased (relative to dedicated survey efforts) perspective on the distribution of these whales feeding off the US West Coast. Satellite tag locations used to derive feeding home ranges were informed by movement model estimated behaviors (i.e., area-restricted search; Mate et al. 2018; Scales et al. 2017) and only included data from tags that transmitted at least 30 days of data.
- Although the majority of the satellite tags included in this assessment were deployed off the southern California coast, several individuals tagged there remained in that region exhibiting feeding behaviors (estimated from state-space model) while others made moved on along the coast further supporting site importance of this region as a feeding ground for fin whales; these grounds are highlighted by the core BIA.
- High proportions of overlapping tagged whale home ranges agree with concentrations of sightings of feeding/milling fin whales and a proportion of the HD model; the HD model extends to areas offshore where small-boat survey efforts have not reached
- Abundance estimates specific to this population are contemporary and based on systematic line-transect survey data (Becker et al., 2020b).
- Core BIA highlights feeding "hotspots" within the broader parent BIA boundary identified by the HD model layer and agreed among higher levels of the sightings and satellite tag data layers
- Tag data is biased to southern California and sightings from small-boat survey efforts are limited relative to other large whale populations of which BIAs are being delineated for

The large size of the BIAs for fin whales makes it challenging to identify more precise critical areas compared to some of the other large whale species. As additional data becomes available, there may be better ways to delineate key core areas. Additionally, while there is some indication of more than one possible population of fin whales using the U.S. West Coast, we did not have a way to specifically incorporate that into our BIAs but this should be an important consideration as more information becomes available.

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Spatiotemporal variability indicator for both parent and core fin whale F-BIAs is static. Large whales (like fin whales) may respond to spatiotemporal variation in the environment and some of the habitat models for large whales have incorporated dynamic variables to try and predict this (Forney et al. 2012, Becker et al 2020a. 2020b, Abrahms et al. 2019a, 2019b). More specifically, common variation in oceanographic conditions along the West Coast region often results in variation in the spatial distribution of large whale prey patches (e.g., krill, anchovies). As such, these whales may adjust their feeding behavior in space and time accordingly. However, we assigned a Spatiotemporal Variability Indicator score of "static" for all BIAs here, due to the following reasons: (1) for BIAs derived from the integrated approach (such as this one), we intentionally attempted to account for year-to-year variability in whale distribution by using multi-year averaged HD model outputs; (2) many of the BIAs' spatial extents cover large areas, such that whale distribution within those areas may change in response to the environment, but the spatial polygons themselves are unlikely to move in space or time.

Boundary certainty: 2

Supporting notes for boundary certainty: We have intermediate confidence in the boundary certainty for both the parent fin whale BIA, although see narrative on spatiotemporal variability above. There is some disagreement between the three supporting data layers, for example, where the HD model extends farther offshore, that creates a discrepancy in our ability to more accurately describe the primary and core feeding ranges for this species. In addition, satellite tagged fin whales off the Oregon and Washington coast represent a small proportion of the data utilized in this assessment; thus, these northern regions may be of higher importance for feeding fin whales, but due to limited effort and sampling in the northern regions our current understanding of their use of these areas for feeding is not as thorough compared to southern regions.

Months of year designation is applicable: June, July, August, September, October, November

Tagging data supporting designation (Y/N): Y

# of tags: 79

# of years in which supporting tagging data collected: 2006-2018 (11 unique years)

Supporting information: Feeding home ranges (HRs) were estimated for 16 fin whales satellite-tagged by OSU and 63 fin whales satellite-tagged by METR along the US west coast from 2006 through 2018 (Mate et al. 2018; Scales et al. 2017). HRs were estimated for individual tagged whales using kernel density estimation methods as described in Mate et al. (2018); details on satellite tag data processing methods are provided as supplementary material. We quantified intensity of space use by mapping each individual's home range on a 10 km x 10 km raster (all on the same grid), summing the total number of home ranges in each cell across all individuals, and calculating the proportion of the total 79 home ranges within each grid cell. For the parent BIA, we chose a proportion of all HRs based on a threshold value of 0.038 (i.e., grid cells greater than 0.038 proportion of all HRs included). For the core BIA, we chose a proportion of all home ranges based on a threshold value of 0.076 proportion of the total 79 HRs.

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 422

# of years in which supporting visual data collected: 1986-2020

Supporting information: Sightings data used for the BIA boundary determinations were collected from dedicated small boat survey efforts conducted by CRC from 1986 through 2020; only sightings where feeding or milling behaviors were observed were included in this assessment (n=422). To create a layer based on this dataset, we used kernel density estimation (KDE) to generate a two-dimensional probability distribution using the package ks (Duong, 2021). The bandwidth value (smoothing parameter) was set to 10 kilometers. For the parent BIA, a broad KDE contour threshold of at least 90% was chosen. For the core BIA, a narrower threshold of 80% was chosen.

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): Y

Supporting information: Faclone et al. 2013, 2018, 2022

Genetic analyses conducted supporting designation (Y/N): Y

Nature of supporting information: Moderate

Supporting information: Archer et al. 2013, 2019

What factors justify the boundary selection?: A combination of sightings data collected from dedicated small boat survey efforts by Cascadia Research Collective (CRC), satellite tag data from long-term implant tags deployed by Oregon State University (OSU), and multi-year averaged habitat-based density (HD) models generated by Southwest Fisheries Science Center (SWFSC) were used to inform BIA boundaries for fin whale feeding BIAs off the US West Coast. For each of the three datasets, two threshold values were chosen: one for creating parent BIAs (i.e., broader distribution) and one for creating child BIAs to represent core areas of use (core BIA, hereafter). Spatial filters were applied to restrict each dataset to the subset of area which met the density or habitat use thresholds. For each of the three data layers (tag HRs, HD model, sightings KDE), there is variability in values across species (or populations): (1) variability in density values across species (or populations) that relates to factors such as the geographic range of the species, behavior of the species, relative abundance, and survey coverage (or sample size of whales tagged); and (2) variability in the spatial sampling across the three data layers, due to the nature of the "survey" methods underlying each layer (i.e., large-scale ship-based line-transect surveys, free movements of tagged whales, localized small-boat surveys). Because of (1), setting exact, quantitative density values for each of the three layers for all species (e.g., 0.005 whales/km2 predicted density for all) would not result in species-specific biologically important areas. While equal quantile-based thresholds could be established across layers to mitigate this (e.g., 0.60 quantile for all data layers), this approach would fail to recognize substantial differences in the spatial scale that each layer reflects (i.e., variation from (2)). Therefore, in attempt to recognize biases that could arise from both (1) and (2) while also maintaining consistency across large whale F-BIAs, we applied a general approach in which threshold values for parent and child BIAs were defined by quantiles specific to each data layer but held the same across species. Layer-specific quantile-based threshold values were justified through expert elicitation (see manuscript for full explanation. The parent BIA HD model layer threshold was specified as the 0.80 quantile, and the core BIA threshold was one quantile higher than the parent BIA threshold (0.90 quantile) for all species. The parent BIA tagged whale home range (HR) threshold was specified as the 0.20 quantile of the total proportion of overlapping HRs and the core BIA threshold value was the 0.30 quantile of the total range of overlapping HRs. Quantiles of the proportion of overlapping HRs were the same across species. For the parent BIAs, the 90% sightings KDE contour was used and for the core BIAs, one intensity level higher (80% sightings KDE contour) was used.

All analyses were conducted within the program R (R Core Team, 2021). The inner (shoreward) boundary of the parent BIA was defined as the 60 m depth contour and the child (core) BIA was defined as the 80 m depth contour, based on the depth frequency of small boat sightings (see supplementary materials for figures). Our intention with these inner boundary definitions was to capture the nearshore nature of this species while recognizing that to some degree their densities decrease with increased distance to shore.

Each of the three data layers relies on different datasets that have their own strengths and weaknesses. The sighting database is limited to just over 400 observations of fin whales feeding or milling but covers fine-scaled survey effort. The tagging data includes 79 deployments with tagging locality bias in southern California but provide detailed patterns of movement over extensive periods, and the habitat-density model is based on sightings from ship-board line-transect surveys covering the entire West Coast including offshore waters but the surveys were conducted only every few years. Combining these data sets to find concurrence in the prediction of high-use regions helps address the individual data set biases and capitalize on their strengths, resulting the most robust way to define BIAs.

Habitat-based density model supporting information:

Multi-year averaged HD model predictions based on data collected from surveys from 1991 to 2018 were used in the BIA boundary determinations; details on survey design and HD modeling methods are described in Becker et al. (2020a, 2020b). The more recent predictions reported in Becker et al. (2020b) do not extend to the Washington US/Canada border. However, earlier HD predictions reported by Becker et al. (2020a) do extend to this northern region, albeit based on lower survey effort (1991-2014), and therefore, the northern portion of predictions from Becker et al. (2020a) were extracted and merged with the Becker et al. (2020b) predictions to create a more complete HD model layer for humpback whales along the U.S. west coast. The parent BIA threshold was 0.014 whales/km2 and the core BIA threshold was 0.024 whales/km2.

Data sources: Oregon State University (accessed 2021); Marine Ecology and Telemetry Research (accessed 2021); Cascadia Research Collective (accessed 2021); Southwest Fisheries Science Center, National Marine Fisheries Serviced (accessed 2021).

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 4

References: Archer, F.I., Morin, P.A., Hancock-Hanser, B.L., Robertson, K.M., Leslie, M.S., Bérubé, M., et al. (2013). Mitogenomic phylogenetics of fin whales (Balaenoptera physalus spp.): genetic evidence for revision of subspecies. PLoS One, 8(5), e63396. doi:10.1371/journal.pone.0063396

Archer, F.I., Brownell Jr, R.L., Hancock-Hanser, B.L., Morin, P.A., Robertson, K.M., Sherman, K.K., et al. (2019). Revision of fin whale Balaenoptera physalus (Linnaeus, 1758) subspecies using genetics. J. Mammal. 100(5), 1653-1670. doi:10.1093/jmammal/gyz121

Becker, E.A., J.V. Caretta, K.A. Forney, J. Barlow, S. Brodie, R. Hoopes, J.G. Jacox, S.M. Maxwell, J.V. Redfern, N.B. Sisson, H. Welch, and E.L. Hazen. 2020a. Performance evaluation of cetacean species distribution models developed using generalized additive models and boosted regression trees. Ecology and Evolution 10:5759-5784 doi:10.1001/ece3.6316

Becker, E.A., K.A. Forney, D.L. Miller, P.C. Fidler, J. Barlow, and J.E. Moore. 2020b. Habitat-based density estimates for cetaceans in the California Current Ecosystem based on 1991-2018 survey data. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-638.

Falcone, E.A., and G.S. Schorr. 2013. Distribution and demographics of marine mammals in SOCAL through photo-identification, genetics, and satellite telemetry: A summary of surveys conducted 1 July 2012 – 30 June 2013. Naval Postgraduate School Technical Report NPS-OC-14-002CR.

Falcone, E.A., Keene, E.L., Rone, B.K., and Schorr, G.S. (2018). Distribution and demographics of fin whales in the Southern California Bight (Final report to the US Navy Pacific Fleet Integrated Comprehensive Monitoring Program, Award No. N66604-17-P-2723)

Falcone, E.A., Keene, E.L., Keen, E.M., Barlow, J., Stewart, J., Cheeseman T., et al. (2022) Movements and residency of fin whales (Balaenoptera physalus) in the California Current System. Mammalian Biology, 1-18. https://doi.org/10.1007/s42991-022-00298-4

Mate, B.R., D.M. Palacios, C.S. Baker, B.A. Lagerquist, L.M. Irvine, T. Follett, D. Steel, C.E. Hayslip, and M.H. Winsor. 2018. Baleen whale tagging in support of marine mammal monitoring across multiple navy training areas covering the years 2014, 2015, 2016, and 2017. Final Report. Prepared for Commander, U.S. Pacific Fleet. Submitted to Naval Facilities Engineering Command Southwest under Contract No. N62470-15-8006-17F4016 issued to HDR Inc., San Diego, California. October 2018

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria https://www.R-project.org/

Scales, K.L., G.S. Schorr, E.L. Hazen, S.J. Bograd, P.I. Miller, R.D. Andrews, A.N. Zerbini, and E.A. Falcone. 2017. Should I stay or should I go? Modelling year-round habitat suitability and drivers of residency for fin whales in the California Current. Diversity and Distributions 23:1204-1215

Schorr, G., E. Falcone, and C. Calambokidis. 2013. Summary of tag deployments on cetaceans off Washington, May 2010 to May 2013. Prepared for Commander, U.S. Pacific Fleet, Pearl Harbor, Hawaii. Submitted to Naval Facilities Engineering Command Pacific (NAVFAC PAC), Pearl Harbor, Hawaii 96860-3134, and Naval Facilities Engineering Command Northwest (NAVFAC NW), Silverdale, WA 98315-1101, under Contract # N62470-10-D-3011, issued to HDR Inc., San Diego, California 92123. 12 June 2013.

Supplementary Description 7. 4. Fin whale feeding area

Species name: Fin whale (*Balaenoptera physalus*)

Descriptive name: Fin whale West Coast - Core

BIA type: Feeding Area

BIA label: F-BIA2-s-b2-WC033-a

Transboundary across: None

Hierarchy: Hierarchical BIA; Child a

Importance score: 2 (Intensity: 2, Data support: 2)

Supporting notes for intensity score: We assigned an Intensity score of 2 for this BIA based on the following reasons:

- Fin whales make migratory movements along the US West Coast to reach productive, high latitude feeding grounds; however previous studies have indicated that not all fin whales undertake seasonal migrations (e.g., Falcone and Schorr, 2013)
- The total abundance estimate for fin whales was recently estimated at 11,065 (CV=0.405) individuals (Becker et al., 2020b), based on species distribution models generated from 1991-2018 line-transect survey data (abundance estimate for 2018 year).
- Fin whales can be found off the US West Coast throughout the year although feeding aggregations begin to increase in late spring, peak in the summer and fall, and decrease in the late fall into winter. This seasonal occurrence aligns with seasonal prey availability along the US West Coast and the feeding BIA described here captures the early summer to late fall period (June through November).
- One other feeding BIA is being delineated for fin whales in the eastern North Pacific (Bering Sea)
- Both parent and core BIAs cover broad areas in this region for all fin whales occurring along the West Coast

Supporting notes for data support score: We assigned a Data Support score of 2 for this BIA based on the following lines of supporting evidence:

- These new feeding BIA boundaries and corresponding time period were informed by a combination of sightings spanning 34 years in total (1986-2020) and restricted to sightings where feeding or milling behaviors were observed.
- The addition of home ranges derived from 79 satellite tagged fin whales since 2006 during 11 unique years provided a more unbiased (relative to dedicated survey efforts) perspective on the distribution of these whales feeding off the US West Coast. Satellite tag locations used to derive feeding home ranges were informed by movement model estimated behaviors (i.e., area-restricted search; Mate et al. 2018; Scales et al. 2017) and only included data from tags that transmitted at least 30 days of data.
- Although the majority of the satellite tags included in this assessment were deployed off the southern California coast, several individuals tagged there remained in that region exhibiting feeding behaviors (estimated from state-space model) while others made moved on along the coast further supporting site importance of this region as a feeding ground for fin whales; these grounds are highlighted by the core BIA.
- High proportions of overlapping tagged whale home ranges agree with concentrations of sightings of feeding/milling fin whales and a proportion of the HD model; the HD model extends to areas offshore where small-boat survey efforts have not reached
- Abundance estimates specific to this population are contemporary and based on systematic line-transect survey data (Becker et al., 2020b).
- Core BIA highlights feeding "hotspots" within the broader parent BIA boundary identified by the HD model layer and agreed among higher levels of the sightings and satellite tag data layers
- Tag data is biased to southern California and sightings from small-boat survey efforts are limited relative to other large whale populations of which BIAs are being delineated for

The large size of the BIAs for fin whales makes it challenging to identify more precise critical areas compared to some of the other large whale species. As additional data becomes available, there may be better ways to delineate key core areas. Additionally, while there is some indication of more than one possible population of fin whales using the U.S. West Coast, we did not have a way to specifically incorporate that into our BIAs but this should be an important consideration as more information becomes available.

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Spatiotemporal variability indicator for both parent and core fin whale F-BIAs is static. Large whales (such as fin whales) may respond to spatiotemporal variation in the environment and some of the habitat models for large whales have incorporated dynamic variables to try and predict this (Forney et al. 2012, Becker et al 2020a. 2020b, Abrahms et al. 2019a, 2019b). More specifically, common variation in oceanographic conditions along the West Coast region often results in variation in the spatial distribution of large whale prey patches (e.g., krill, anchovies). As such, these whales may adjust their feeding behavior in space and time accordingly. However, we assigned a Spatiotemporal Variability Indicator score of "static" for all BIAs here, due to the following reasons: (1) for BIAs derived from the integrated approach (such as this one), we intentionally attempted to account for year-to-year variability in whale distribution by using multi-year averaged HD model outputs; (2) many of the BIAs' spatial extents cover large areas, such that whale distribution within those areas may change in response to the environment, but the spatial polygons themselves are unlikely to move in space or time.

Boundary certainty: 2

Supporting notes for boundary certainty: We have intermediate confidence in the boundary certainty for both the core fin whale BIA, although see narrative on spatiotemporal variability above. There is some disagreement between the three supporting data layers, for example, where the HD model extends farther offshore, that creates a discrepancy in our ability to more accurately describe the primary and core feeding ranges for this species. In addition, satellite tagged fin whales off the Oregon and Washington coast represent a small proportion of the data utilized in this assessment; thus, these northern regions may be of higher importance for feeding fin whales, but due to limited effort and sampling in the northern regions our current understanding of their use of these areas for feeding is not as thorough compared to southern regions.

Months of year designation is applicable: June, July, August, September, October, November

Tagging data supporting designation (Y/N): Y

# of tags: 79

# of years in which supporting tagging data collected: 2006-2018 (11 unique years)

Supporting information: Feeding home ranges (HRs) were estimated for 16 fin whales satellite-tagged by OSU and 63 fin whales satellite-tagged by METR along the US west coast from 2006 through 2018 (Mate et al. 2018; Scales et al. 2017). HRs were estimated for individual tagged whales using kernel density estimation methods as described in Mate et al. (2018); details on satellite tag data processing methods are provided as supplementary material. We quantified intensity of space use by mapping each individual's home range on a 10 km x 10 km raster (all on the same grid), summing the total number of home ranges in each cell across all individuals, and calculating the proportion of the total 79 home ranges within each grid cell. For the parent BIA, we chose a proportion of all HRs based on a threshold value of 0.038 (i.e., grid cells greater than 0.038 proportion of all HRs included). For the core BIA, we chose a proportion of all home ranges based on a threshold value of 0.076 proportion of the total 79 HRs.

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 422

# of years in which supporting visual data collected: 1986-2020

Supporting information: Sightings data used for the BIA boundary determinations were collected from dedicated small boat survey efforts conducted by CRC from 1986 through 2020; only sightings where feeding or milling behaviors were observed were included in this assessment (n=422). To create a layer based on this dataset, we used kernel density estimation (KDE) to generate a two-dimensional probability distribution using the package ks (Duong, 2021). The bandwidth value (smoothing parameter) was set to 10 kilometers. For the parent BIA, a broad KDE contour threshold of at least 90% was chosen. For the core BIA, a narrower threshold of 80% was chosen.

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): Y

Supporting information: Falcone et al. 2013, 2018, 2022

Genetic analyses conducted supporting designation (Y/N): Y

Nature of supporting information: Moderate

Supporting information: Archer et al. 2013, 2019

What factors justify the boundary selection?: A combination of sightings data collected from dedicated small boat survey efforts by Cascadia Research Collective (CRC), satellite tag data from long-term implant tags deployed by Oregon State University (OSU), and multi-year averaged habitat-based density (HD) models generated by Southwest Fisheries Science Center (SWFSC) were used to inform BIA boundaries for fin whale feeding BIAs off the US West Coast. For each of the three datasets, two threshold values were chosen: one for creating parent BIAs (i.e., broader distribution) and one for creating child BIAs to represent core areas of use (core BIA, hereafter). Spatial filters were applied to restrict each dataset to the subset of area which met the density or habitat use thresholds. For each of the three data layers (tag HRs, HD model, sightings KDE), there is variability in values across species (or populations): (1) variability in density values across species (or populations) that relates to factors such as the geographic range of the species, behavior of the species, relative abundance, and survey coverage (or sample size of whales tagged); and (2) variability in the spatial sampling across the three data layers, due to the nature of the "survey" methods underlying each layer (i.e., large-scale ship-based line-transect surveys, free movements of tagged whales, localized small-boat surveys). Because of (1), setting exact, quantitative density values for each of the three layers for all species (e.g., 0.005 whales/km2 predicted density for all) would not result in species-specific biologically important areas. While equal quantile-based thresholds could be established across layers to mitigate this (e.g., 0.60 quantile for all data layers), this approach would fail to recognize substantial differences in the spatial scale that each layer reflects (i.e., variation from (2)). Therefore, in attempt to recognize biases that could arise from both (1) and (2) while also maintaining consistency across large whale F-BIAs, we applied a general approach in which threshold values for parent and child BIAs were defined by quantiles specific to each data layer but held the same across species. Layer-specific quantile-based threshold values were justified through expert elicitation (see manuscript for full explanation. The parent BIA HD model layer threshold was specified as the 0.80 quantile, and the core BIA threshold was one quantile higher than the parent BIA threshold (0.90 quantile) for all species. The parent BIA tagged whale home range (HR) threshold was specified as the 0.20 quantile of the total proportion of overlapping HRs and the core BIA threshold value was the 0.30 quantile of the total range of overlapping HRs. Quantiles of the proportion of overlapping HRs were the same across species. For the parent BIAs, the 90% sightings KDE contour was used and for the core BIAs, one intensity level higher (80% sightings KDE contour) was used.

All analyses were conducted within the program R (R Core Team, 2021). The inner (shoreward) boundary of the parent BIA was defined as the 60 m depth contour and the child (core) BIA was defined as the 80 m depth contour, based on the depth frequency of small boat sightings (see supplementary materials for figures). Our intention with these inner boundary definitions was to capture the nearshore nature of this species while recognizing that to some degree their densities decrease with increased distance to shore.

Each of the three data layers relies on different datasets that have their own strengths and weaknesses. The sighting database is limited to just over 400 observations of fin whales feeding or milling but covers fine-scaled survey effort. The tagging data includes 79 deployments with tagging locality bias in southern California but provide detailed patterns of movement over extensive periods, and the habitat-density model is based on sightings from ship-board line-transect surveys covering the entire West Coast including offshore waters but the surveys were conducted only every few years. Combining these data sets to find concurrence in the prediction of high-use regions helps address the individual data set biases and capitalize on their strengths, resulting the most robust way to define BIAs.

Habitat-based density model supporting information:

Multi-year averaged HD model predictions based on data collected from surveys from 1991 to 2018 were used in the BIA boundary determinations; details on survey design and HD modeling methods are described in Becker et al. (2020a, 2020b). The more recent predictions reported in Becker et al. (2020b) do not extend to the Washington US/Canada border. However, earlier HD predictions reported by Becker et al. (2020a) do extend to this northern region, albeit based on lower survey effort (1991-2014), and therefore, the northern portion of predictions from Becker et al. (2020a) were extracted and merged with the Becker et al. (2020b) predictions to create a more complete HD model layer for humpback whales along the U.S. west coast. The parent BIA threshold was 0.014 whales/km2 and the core BIA threshold was 0.024 whales/km2.

Data sources: Oregon State University (accessed 2021); Marine Ecology and Telemetry Research (accessed 2021); Cascadia Research Collective (accessed 2021); Southwest Fisheries Science Center, National Marine Fisheries Service (accessed 2021).

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 4

References: Archer, F.I., Morin, P.A., Hancock-Hanser, B.L., Robertson, K.M., Leslie, M.S., Bérubé, M., et al. (2013). Mitogenomic phylogenetics of fin whales (Balaenoptera physalus spp.): genetic evidence for revision of subspecies. PLoS One, 8(5), e63396. doi:10.1371/journal.pone.0063396

Archer, F.I., Brownell Jr, R.L., Hancock-Hanser, B.L., Morin, P.A., Robertson, K.M., Sherman, K.K., et al. (2019). Revision of fin whale Balaenoptera physalus (Linnaeus, 1758) subspecies using genetics. J. Mammal. 100(5), 1653-1670. doi:10.1093/jmammal/gyz121

Becker, E.A., J.V. Caretta, K.A. Forney, J. Barlow, S. Brodie, R. Hoopes, J.G. Jacox, S.M. Maxwell, J.V. Redfern, N.B. Sisson, H. Welch, and E.L. Hazen. 2020a. Performance evaluation of cetacean species distribution models developed using generalized additive models and boosted regression trees. Ecology and Evolution 10:5759-5784 doi:10.1001/ece3.6316

Becker, E.A., K.A. Forney, D.L. Miller, P.C. Fidler, J. Barlow, and J.E. Moore. 2020b. Habitat-based density estimates for cetaceans in the California Current Ecosystem based on 1991-2018 survey data. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-638.

Falcone, E.A., and G.S. Schorr. 2013. Distribution and demographics of marine mammals in SOCAL through photo-identification, genetics, and satellite telemetry: A summary of surveys conducted 1 July 2012 – 30 June 2013. Naval Postgraduate School Technical Report NPS-OC-14-002CR.

Falcone, E.A., Keene, E.L., Rone, B.K., and Schorr, G.S. (2018). Distribution and demographics of fin whales in the Southern California Bight (Final report to the US Navy Pacific Fleet Integrated Comprehensive Monitoring Program, Award No. N66604-17-P-2723)

Falcone, E.A., Keene, E.L., Keen, E.M., Barlow, J., Stewart, J., Cheeseman T., et al. (2022) Movements and residency of fin whales (Balaenoptera physalus) in the California Current System. Mammalian Biology, 1-18. https://doi.org/10.1007/s42991-022-00298-4

Mate, B.R., D.M. Palacios, C.S. Baker, B.A. Lagerquist, L.M. Irvine, T. Follett, D. Steel, C.E. Hayslip, and M.H. Winsor. 2018. Baleen whale tagging in support of marine mammal monitoring across multiple navy training areas covering the years 2014, 2015, 2016, and 2017. Final Report. Prepared for Commander, U.S. Pacific Fleet. Submitted to Naval Facilities Engineering Command Southwest under Contract No. N62470-15-8006-17F4016 issued to HDR Inc., San Diego, California. October 2018

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria https://www.R-project.org/

Scales, K.L., G.S. Schorr, E.L. Hazen, S.J. Bograd, P.I. Miller, R.D. Andrews, A.N. Zerbini, and E.A. Falcone. 2017. Should I stay or should I go? Modelling year-round habitat suitability and drivers of residency for fin whales in the California Current. Diversity and Distributions 23:1204-1215

Schorr, G., E. Falcone, and C. Calambokidis. 2013. Summary of tag deployments on cetaceans off Washington, May 2010 to May 2013. Prepared for Commander, U.S. Pacific Fleet, Pearl Harbor, Hawaii. Submitted to Naval Facilities Engineering Command Pacific (NAVFAC PAC), Pearl Harbor, Hawaii 96860-3134, and Naval Facilities Engineering Command Northwest (NAVFAC NW), Silverdale, WA 98315-1101, under Contract # N62470-10-D-3011, issued to HDR Inc., San Diego, California 92123. 12 June 2013.

Supplementary Description 7. 5. Gray whale feeding area

Species name: Gray whale (*Eschrichtius robustus*)

Stock or population: Pacific Coast Feeding Group

Descriptive name: Pacific Coast Feeding Group - Parent

BIA type: Feeding Area

BIA label: F-BIA2-s-b3-WC034-0a

Transboundary across: None

Hierarchy: Hierarchical BIA; Parent of children a

Importance score: 2 (Intensity: 2, Data support: 3)

Supporting notes for intensity score: We assigned this BIA an Intensity score of 2 based on the following reasons:

PCFG gray whales make extensive movements from low-latitude breeding grounds off Baja to productive, high-latitude feeding grounds off the US West Coast, with most feeding PCFG gray whales concentrated off the northern California, central Oregon, and central and northern Washington coasts, as first identified in Calambokidis et al., (2015) and now expanded by this revised BIA.
• The total abundance estimate for PCFG gray whales was recently estimated at 243 (SE=18.9) individuals (Calambokidis et al., 2017) based on photographic data from 1998 through 2015.
• Gray whales can be found off the US West Coast throughout the year although feeding aggregations begin to increase in late spring, peak in the summer and fall, and decrease in the late fall into winter. This seasonal occurrence aligns with seasonal prey availability along the US West Coast and the feeding BIA described here captures the early summer to late fall period (June through November).
• Although other feeding BIAs are being delineated for gray whales in the eastern North Pacific, the PCFG gray whales considered here have a relatively restricted feeding range along the US west coast with some extension farther north, highlighting the importance of the BIA described here for the small PCFG gray whale population

Supporting notes for data support score: We assigned a Data Support score of 3 for this BIA based on the following lines of supporting evidence:

These revised feeding BIA boundaries and corresponding time period were informed by additional sightings obtained since the initial 2015 effort, spanning 29 years in total (1992-2020), and restricted to sightings where feeding or milling behaviors were observed.
• The addition of home ranges derived from 23 satellite tagged PCFG gray whales since 2009 provided a more unbiased (relative to dedicated survey efforts) perspective on the distribution of these whales feeding off the US West Coast. Satellite tag locations used to derive feeding home ranges were informed by movement model estimated behaviors (i.e., area-restricted search; Lagerquist et al., 2019) and only included data from tags that transmitted at least 30 days of data (or 50 state-space modeled locations, estimated at two per day).
• Although the majority of the satellite tags included in this assessment were deployed off the northern California coast, individuals tagged here generally remained within the stretch of the northern California/southern Oregon coast further supporting site importance of this region as a feeding ground for PCFG gray whales; these grounds are highlighted by the child (core) BIA.
• High proportions of overlapping tagged whale home ranges agree with concentrations of sightings of feeding/milling gray whales, that were originally used to draw the 2015 boundaries.
• Abundance estimates specific to this population are contemporary and based on long-term sighting and photographic data (Calambokidis et al., 2017).
• Core BIA highlights feeding “hotspots” within the broader parent BIA boundary agreed among higher levels of both sightings and satellite tag data

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: The BIA boundaries for PCFG whales are static, although variability in areas of feeding for PCFG whales does vary year to year. The environmental factors that would predict this have not been well described.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainty for both the parent and core PCFG gray whale feeding BIAs along the west coast described in this assessment, even though there is some seasonal and annual variability in the areas PCFG whales feed. This boundary is supported by two independent data sources (sightings from small-boat surveys and home ranges from long-term satellite tag deployments) and combined have complementary strengths and weaknesses. The parent BIA boundary characterized here encompasses nearly all visual sightings of feeding or milling PCFG gray whales documented from 1992 through 2020 (during June-November feeding season); and (2) a large proportion of shared home ranges from satellite tagged PCFG gray whales. The resulting core BIA reflects higher intensity values of satellite tagged whales that agree with concentrations of sighting locations.

Months of year designation is applicable: June, July, August, September, October, November

Tagging data supporting designation (Y/N): Y

# of tags: 23

# of years in which supporting tagging data collected: 2009-2013 (3 unique years)

Supporting information: Feeding home ranges (HR) were estimated for 23 PCFG gray whales satellite-tagged by OSU off Central Oregon and Northern California from 2009 through 2013 (Lagerquist et al., 2019). HRs were estimated for individual tagged whales using kernel density estimation methods as described in Lagerquist et al., (2019); details on satellite tag data processing methods are provided as supplementary material. We quantified intensity of space use by mapping each individual's home range on a 1 km x 1 km raster (all on the same grid), summing the total number of home ranges in each cell across all individuals, and calculating the proportion of the total 23 home ranges within each grid cell. For the parent BIA, we chose a proportion of all home ranges based on a threshold value of 0.05 (i.e., grid cells with greater than 0.05 proportion of all home ranges included). For the core BIA, a threshold value of 0.131 proportion of the total 23 home ranges was chosen.

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 403

# of years in which supporting visual data collected: 1992-2020

Supporting information: Sightings data used for the BIA boundary determinations were collected from dedicated small boat survey efforts conducted by CRC from 1992 through 2020; only sightings where feeding or milling behaviors were observed were included in this assessment. There was a total of 403 sightings during the PCFG gray whale feeding season (June-November). To create a layer based on this dataset, we used kernel density estimation (KDE) to generate a two-dimensional probability distribution using the package ks (Duong, 2021). The bandwidth value (smoothing parameter) was set to 5 kilometers. For the parent BIA, a broad KDE contour threshold of at least 90% was chosen. For the core BIA, a narrower threshold of 80% was chosen.

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): Y

# of years of photo records to compare: 1998-2021

Supporting information: Calambokidis et al., 2017; CRC unpublished

Genetic analyses conducted supporting designation (Y/N): Y

Nature of supporting information: Strong

Supporting information: Frasier et al. 2011; Lang et al. 2014

What factors justify the boundary selection?: A combination of sightings data collected from dedicated small boat survey efforts by Cascadia Research Collective (CRC), satellite tag data from long-term implant tags deployed by Oregon State University (OSU), and multi-year averaged habitat-based density (HD) models generated by Southwest Fisheries Science Center (SWFSC) were used to inform BIA boundaries for fin whale feeding BIAs off the US West Coast. For each of the three datasets, two threshold values were chosen: one for creating parent BIAs (i.e., broader distribution) and one for creating child BIAs to represent core areas of use (core BIA, hereafter). Spatial filters were applied to restrict each dataset to the subset of area which met the density or habitat use thresholds. For each of the three data layers (tag HRs, HD model, sightings KDE), there is variability in values across species (or populations): (1) variability in density values across species (or populations) that relates to factors such as the geographic range of the species, behavior of the species, relative abundance, and survey coverage (or sample size of whales tagged); and (2) variability in the spatial sampling across the three data layers, due to the nature of the "survey" methods underlying each layer (i.e., large-scale ship-based line-transect surveys, free movements of tagged whales, localized small-boat surveys). Because of (1), setting exact, quantitative density values for each of the three layers for all species (e.g., 0.005 whales/km2 predicted density for all) would not result in species-specific biologically important areas. While equal quantile-based thresholds could be established across layers to mitigate this (e.g., 0.60 quantile for all data layers), this approach would fail to recognize substantial differences in the spatial scale that each layer reflects (i.e., variation from (2)). Therefore, in attempt to recognize biases that could arise from both (1) and (2) while also maintaining consistency across large whale F-BIAs, we applied a general approach in which threshold values for parent and child BIAs were defined by quantiles specific to each data layer but held the same across species. Layer-specific quantile-based threshold values were justified through expert elicitation (see manuscript for full explanation. The parent BIA HD model layer threshold was specified as the 0.80 quantile, and the core BIA threshold was one quantile higher than the parent BIA threshold (0.90 quantile) for all species. The parent BIA tagged whale home range (HR) threshold was specified as the 0.20 quantile of the total proportion of overlapping HRs and the core BIA threshold value was the 0.30 quantile of the total range of overlapping HRs. Quantiles of the proportion of overlapping HRs were the same across species. For the parent BIAs, the 90% sightings KDE contour was used and for the core BIAs, one intensity level higher (80% sightings KDE contour) was used. All analyses were conducted within the program R (R Core Team, 2021).

No habitat density model estimates were available to include in the delineation of PCFG gray whale BIAs, and thus only the satellite tag data HR and sightings KDE layers were incorporated into this assessment.

Each of the three data layers relies on different datasets that have their own strengths and weaknesses. The sighting database is based on more than 400 observations of gray whales feeding or milling but is biased by the uneven distribution of effort. The tagging data includes 23 deployments with tagging locality bias in northern California but provide detailed patterns of movement over extensive periods. Integrating these two datasets and looking at areas of agreement (overlap) provides the most comprehensive way to set BIAs, taking into consideration the potential strengths and biases of each dataset.

Data sources: Oregon State University (accessed 2021); Cascadia Research Collective (accessed 2021)

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 1

References: Calambokidis J, Evenson JR, Chandler TE, Steiger GH (1992) Individual identification of gray whales in Puget Sound in 1991. Puget Sound Notes 28:1-4.

Calambokidis J, Darling JD, Deecke V, Gearin P, Gosho M, Megill W et al. (2002) Abundance, range and movements of a feeding aggregation of gray whales (Eschrichtius robustus) from California to southeastern Alaska in 1998. Journal of Cetacean Research and Management 4:267-276. http://www.cascadiaresearch.org/reports/ER-JCRM-02.pdf

Duong, T. 2021. Ks: Kernel Smooth. R package version 1.13.2. https://CRAN.R-project.org/package=ks

Frasier, T.R., Koroscil, S.M., White, B.N., and Darling, J.D. (2011). Assessment of population substructure in relation to summer feeding ground use in the eastern North Pacific gray whale. Endanger. Species Res. 14, 39-48. Doi:10.3354/esr00340

Lagerquist, B.A., D.M. Palacios, M.H. Winsor, L.M. Irvine, T.M. Follett, and B.R. Mate. 2019. Feeding home ranges of pacific coast feeding group gray whales. The Journal of Wildlife Management 83(4):925-937.

Lang, A.R., Calambokidis, J., Scordino, J., Pease, V.L., Klimek, A., Burkanov, V.N., et al. (2014). Assessment of genetic structure among eastern North Pacific gray whales on their feeding grounds. Mar. Mamm. Sci. 30(4), 1473-1493. Doi:10.1111/mms.12129

Mate, B.R., D.M. Palacios, C.S. Baker, B.A. Lagerquist, L.M. Irvine, T. Follett, D. Steel, C.E. Hayslip, and M.H. Winsor. 2018. Baleen whale tagging in support of marine mammal monitoring across multiple navy training areas covering the years 2014, 2015, 2016, and 2017. Final Report. Prepared for Commander, U.S. Pacific Fleet. Submitted to Naval Facilities Engineering Command Southwest under Contract No. N62470-15-8006-17F4016 issued to HDR Inc., San Diego, California. October 2018

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria https://www.R-project.org/

Supplementary Description 7. 6. Gray whale feeding area

Species name: Gray whale (*Eschrichtius robustus*)

Stock or population: Pacific Coast Feeding Group

Descriptive name: Pacific Coast Feeding Group - Core

BIA type: Feeding Area

BIA label: F-BIA3-s-b3-WC034-a

Transboundary across: None

Hierarchy: Hierarchical BIA; Child a

Importance score: 3 (Intensity: 3, Data support: 3)

Supporting notes for intensity score: We assigned an Intensity score of 3 for this BIA based on the following reasons:

- PCFG gray whales make extensive movements from low-latitude breeding grounds off Baja to productive, high-latitude feeding grounds off the US West Coast, with most feeding PCFG gray whales concentrated off the northern California, central Oregon, and central and northern Washington coasts, as first identified in Calambokidis et al., (2015) and now expanded by this revised BIA.
- The total abundance estimate for PCFG gray whales was recently estimated at 243 (SE=18.9) individuals (Calambokidis et al., 2017) based on photographic data from 1998 through 2015.
- Gray whales can be found off the US West Coast throughout the year although feeding aggregations begin to increase in late spring, peak in the summer and fall, and decrease in the late fall into winter. This seasonal occurrence aligns with seasonal prey availability along the US West Coast and the feeding BIA described here captures the early summer to late fall period (June through November).
- Although other feeding BIAs are being delineated for gray whales in the eastern North Pacific, the PCFG gray whales considered here have a relatively restricted feeding range along the US west coast with some extension farther north, highlighting the importance of the BIA described here for the small PCFG gray whale population

Supporting notes for data support score: We assigned a Data Support score of 3 for this BIA based on the following lines of supporting evidence:

- These revised feeding BIA boundaries and corresponding time period were informed by additional sightings obtained since the initial 2015 effort, spanning 29 years in total (1992-2020), and restricted to sightings where feeding or milling behaviors were observed.
- The addition of home ranges derived from 23 satellite tagged PCFG gray whales since 2009 provided a more unbiased (relative to dedicated survey efforts) perspective on the distribution of these whales feeding off the US West Coast. Satellite tag locations used to derive feeding home ranges were informed by movement model estimated behaviors (i.e., area-restricted search; Lagerquist et al., 2019) and only included data from tags that transmitted at least 30 days of data (or 50 state-space modeled locations, estimated at two per day).
- Although the majority of the satellite tags included in this assessment were deployed off the northern California coast, individuals tagged here generally remained within the stretch of the northern California/southern Oregon coast further supporting site importance of this region as a feeding ground for PCFG gray whales; these grounds are highlighted by the child (core) BIA.
- High proportions of overlapping tagged whale home ranges agree with concentrations of sightings of feeding/milling gray whales, that were originally used to draw the 2015 boundaries.
- Abundance estimates specific to this population are contemporary and based on long-term sighting and photographic data (Calambokidis et al., 2017).
- Core BIA highlights feeding "hotspots" within the broader parent BIA boundary agreed among higher levels of both sightings and satellite tag data

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: The BIA boundaries for PCFG whales are static, although variability in areas of feeding for PCFG whales does vary year to year. The environmental factors that would predict this have not been well described.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainty for both the parent and core PCFG gray whale feeding BIAs along the west coast described in this assessment, even though there is some seasonal and annual variability in the areas PCFG whales feed. This boundary is supported by two independent data sources (sightings from small-boat surveys and home ranges from long-term satellite tag deployments) and combined have complementary strengths and weaknesses. The parent BIA boundary characterized here encompasses nearly all visual sightings of feeding or milling PCFG gray whales documented from 1992 through 2020 (during June-November feeding season); and (2) a large proportion of shared home ranges from satellite tagged PCFG gray whales. The resulting core BIA reflects higher intensity values of satellite tagged whales that agree with concentrations of sighting locations.

Months of year designation is applicable: June, July, August, September, October, November

Tagging data supporting designation (Y/N): Y

# of tags: 23

# of years in which supporting tagging data collected: 2009-2013 (3 unique years)

Supporting information: Feeding home ranges (HR) were estimated for 23 PCFG gray whales satellite-tagged by OSU off Central Oregon and Northern California from 2009 through 2013 (Lagerquist et al., 2019). HRs were estimated for individual tagged whales using kernel density estimation methods as described in Lagerquist et al., (2019); details on satellite tag data processing methods are provided as supplementary material. We quantified intensity of space use by mapping each individual's home range on a 1 km x 1 km raster (all on the same grid), summing the total number of home ranges in each cell across all individuals, and calculating the proportion of the total 23 home ranges within each grid cell. For the parent BIA, we chose a proportion of all home ranges based on a threshold value of 0.05 (i.e., grid cells with greater than 0.05 proportion of all home ranges included). For the core BIA, a threshold value of 0.131 proportion of the total 23 home ranges was chosen.

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 403

# of years in which supporting visual data collected: 1992-2020

Supporting information: Sightings data used for the BIA boundary determinations were collected from dedicated small boat survey efforts conducted by CRC from 1992 through 2020; only sightings where feeding or milling behaviors were observed were included in this assessment. There was a total of 403 sightings during the PCFG gray whale feeding season (June-November). To create a layer based on this dataset, we used kernel density estimation (KDE) to generate a two-dimensional probability distribution using the package ks (Duong, 2021). The bandwidth value (smoothing parameter) was set to 5 kilometers. For the parent BIA, a broad KDE contour threshold of at least 90% was chosen. For the core BIA, a narrower threshold of 80% was chosen.

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): Y

# of years of photo records to compare: 1998-2021

Supporting information: Calambokidis et al. 2017, CRC unpublished

Genetic analyses conducted supporting designation (Y/N): Y

Nature of supporting information: Strong

Supporting information: Frasier et al., 2011; Lang et al., 2014

What factors justify the boundary selection?: A combination of sightings data collected from dedicated small boat survey efforts by Cascadia Research Collective (CRC), satellite tag data from long-term implant tags deployed by Oregon State University (OSU), and multi-year averaged habitat-based density (HD) models generated by Southwest Fisheries Science Center (SWFSC) were used to inform BIA boundaries for fin whale feeding BIAs off the US West Coast. For each of the three datasets, two threshold values were chosen: one for creating parent BIAs (i.e., broader distribution) and one for creating child BIAs to represent core areas of use (core BIA, hereafter). Spatial filters were applied to restrict each dataset to the subset of area which met the density or habitat use thresholds. For each of the three data layers (tag HRs, HD model, sightings KDE), there is variability in values across species (or populations): (1) variability in density values across species (or populations) that relates to factors such as the geographic range of the species, behavior of the species, relative abundance, and survey coverage (or sample size of whales tagged); and (2) variability in the spatial sampling across the three data layers, due to the nature of the "survey" methods underlying each layer (i.e., large-scale ship-based line-transect surveys, free movements of tagged whales, localized small-boat surveys). Because of (1), setting exact, quantitative density values for each of the three layers for all species (e.g., 0.005 whales/km2 predicted density for all) would not result in species-specific biologically important areas. While equal quantile-based thresholds could be established across layers to mitigate this (e.g., 0.60 quantile for all data layers), this approach would fail to recognize substantial differences in the spatial scale that each layer reflects (i.e., variation from (2)). Therefore, in attempt to recognize biases that could arise from both (1) and (2) while also maintaining consistency across large whale F-BIAs, we applied a general approach in which threshold values for parent and child BIAs were defined by quantiles specific to each data layer but held the same across species. Layer-specific quantile-based threshold values were justified through expert elicitation (see manuscript for full explanation. The parent BIA HD model layer threshold was specified as the 0.80 quantile, and the core BIA threshold was one quantile higher than the parent BIA threshold (0.90 quantile) for all species. The parent BIA tagged whale home range (HR) threshold was specified as the 0.20 quantile of the total proportion of overlapping HRs and the core BIA threshold value was the 0.30 quantile of the total range of overlapping HRs. Quantiles of the proportion of overlapping HRs were the same across species. For the parent BIAs, the 90% sightings KDE contour was used and for the core BIAs, one intensity level higher (80% sightings KDE contour) was used. All analyses were conducted within the program R (R Core Team, 2021).

No habitat density model estimates were available to include in the delineation of PCFG gray whale BIAs, and thus only the satellite tag data HR and sightings KDE layers were incorporated into this assessment.

Each of the three data layers relies on different datasets that have their own strengths and weaknesses. The sighting database is based on more than 400 observations of gray whales feeding or milling but is biased by the uneven distribution of effort. The tagging data includes 23 deployments with tagging locality bias in northern California but provide detailed patterns of movement over extensive periods. Integrating these two datasets and looking at areas of agreement (overlap) provides the most comprehensive way to set BIAs, taking into consideration the potential strengths and biases of each dataset.

Data sources: Oregon State University (accessed 2021); Cascadia Research Collective (accessed 2021)

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 1

References: Calambokidis J, Evenson JR, Chandler TE, Steiger GH (1992) Individual identification of gray whales in Puget Sound in 1991. Puget Sound Notes 28:1-4.

Calambokidis J, Darling JD, Deecke V, Gearin P, Gosho M, Megill W et al. (2002) Abundance, range and movements of a feeding aggregation of gray whales (Eschrichtius robustus) from California to southeastern Alaska in 1998. Journal of Cetacean Research and Management 4:267-276. http://www.cascadiaresearch.org/reports/ER-JCRM-02.pdf

Duong, T. 2021. Ks: Kernel Smooth. R package version 1.13.2. https://CRAN.R-project.org/package=ks

Frasier, T.R., Koroscil, S.M., White, B.N., and Darling, J.D. (2011). Assessment of population substructure in relation to summer feeding ground use in the eastern North Pacific gray whale. Endanger. Species Res. 14, 39-48. Doi:10.3354/esr00340

Lagerquist, B.A., D.M. Palacios, M.H. Winsor, L.M. Irvine, T.M. Follett, and B.R. Mate. 2019. Feeding home ranges of pacific coast feeding group gray whales. The Journal of Wildlife Management 83(4):925-937.

Lang, A.R., Calambokidis, J., Scordino, J., Pease, V.L., Klimek, A., Burkanov, V.N., et al. (2014). Assessment of genetic structure among eastern North Pacific gray whales on their feeding grounds. Mar. Mamm. Sci. 30(4), 1473-1493. Doi:10.1111/mms.12129

Mate, B.R., D.M. Palacios, C.S. Baker, B.A. Lagerquist, L.M. Irvine, T. Follett, D. Steel, C.E. Hayslip, and M.H. Winsor. 2018. Baleen whale tagging in support of marine mammal monitoring across multiple navy training areas covering the years 2014, 2015, 2016, and 2017. Final Report. Prepared for Commander, U.S. Pacific Fleet. Submitted to Naval Facilities Engineering Command Southwest under Contract No. N62470-15-8006-17F4016 issued to HDR Inc., San Diego, California. October 2018

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria https://www.R-project.org/

Supplementary Description 7. 7. Gray whale feeding area

Species name: Gray whale (*Eschrichtius robustus*)

Descriptive name: Sounders - Northern Puget Sound

BIA type: Feeding Area

BIA label: F-BIA2-s-b3-WC010-0

Transboundary across: None

Hierarchy: Non-hierarchical; single BIA

Importance score: 2 (Intensity: 2, Data support: 3)

Supporting notes for intensity score: We assigned an Intensity score of 2 for this BIA based on the following reasons:

- Roughly a dozen gray whales that break off from their migration route to feed in northern Puget Sound from February through June peaking March through May, before heading north to summer feeding grounds in the Bering and Chukchi seas
- This particular group of gray whales appear to exclusively feed on aggregations of ghost shrimp in highly productive intertidal zones (at high tide) of northern Puget Sound (Calambokidis, 2016)
- Resighting rates of photo-identified individuals over 20 years in this region indicate the area serves as important feeding habitat that is depended on year-to-year (Calambokidis et al., 2014, 2019)
- Other feeding BIAs are being delineated for gray whales in the Eastern North Pacific, however this particular BIA for northern Puget Sound serves as an important feeding ground for a specific group of gray whales that exhibit high site fidelity to the area, and during a relatively short time period. The Northern Puget Sound is largely not the sole feeding ground for this particular group of gray whales during this shorter period. However, if recent changes in the number of gray whales using this area for feeding and the timing of arrival and departure continue then this BIA and corresponding scoring could be modified appropriately in the future.

Supporting notes for data support score: We assigned a Data Support score of 3 for this BIA based on the following lines of support:

- Long-term photo-ID data supporting use of this area since 1990 and year-to-year use of this area by a set of identified individuals, with individual resighting rates documented over 20 years (Calambokidis, 2016; Calambokidis et al., 2014, 2019)
- Concentrations of sightings used to draw the original 2015 boundary agree with additional feeding observations accrued since the 2015 assessment (Calambokidis et al., 2015)
- Feeding in this area is supported through both visual observations and information from CATs tag deployments (Calambokidis, 2016)
- Since the initial 2015 study, additional information on the distribution of this group has supported the expansion of the BIA boundary to include the rest of Port Susan
- In contrast to the 2015 assessment, only sightings that were collected by CRC and had documented feeding/milling behaviors were considered in this assessment. The distribution of sightings remains generally the same even with the more restricted dataset.

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: We describe a static boundary because the area that the Sounders use is very small and relatively consistent year to year and through the season that they use it.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainty for the Sounders gray whale feeding BIA in northern Puget Sound. CRC re-sightings of photo-identified individuals feeding in this region span a period of 27 years (1994-2020). The BIA revised here encompasses nearly all gray whale sighting locations during the February-June feeding season in this region and captures emerging areas of importance that were not previously recognized in the 2015 assessment (Calambokidis et al., 2015).

Months of year designation is applicable: February, March, April, May, June

Tagging data supporting designation (Y/N): N

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 402

# of years in which supporting visual data collected: 1994-2020

Supporting information: Sightings data used for the BIA boundary determinations were collected from dedicated small boat survey efforts conducted by CRC from 1994 through 2020; only sightings where feeding or milling behaviors were observed were included in this assessment. There was a total of 402 sightings of feeding or milling gray whales in northern Puget Sound during the February-June feeding season.

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): Y

# of years of photo records to compare: 27 (1994-2020)

Maximum # of years same individual photographed in area: over 20 yrs

Supporting information: Calambokidis, 2016; Calambokidis et al., 2014, 2019

Genetic analyses conducted supporting designation (Y/N): N

What factors justify the boundary selection?: Sightings data collected from dedicated small boat survey efforts by Cascadia Research Collective (CRC) were used to revise the feeding BIA boundary for "Sounders" gray whales in Northern Puget Sound. The Sounders gray whale BIA spans February through June, with peak use from March to May, and some indications the period of use of this area has expanded in recent years. Revised boundary was expanded to encompass areas of emerging use based on sightings/field observations and expert elicitation. All analyses were conducted within the program R (R Core Team, 2021).

Data sources: Cascadia Research Collective (accessed 2021)

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 1

References: Calambokidis J, Evenson JR, Chandler TE, Steiger GH (1992) Individual identification of gray whales in Puget Sound in 1991. Puget Sound Notes 28:1-4.

Calambokidis J, Darling JD, Deecke V, Gearin P, Gosho M, Megill W et al. (2002) Abundance, range and movements of a feeding aggregation of gray whales (Eschrichtius robustus) from California to southeastern Alaska in 1998. Journal of Cetacean Research and Management 4:267-276. http://www.cascadiaresearch.org/reports/ER-JCRM-02.pdf

Calambokidis, J., J. Laake, and A. Perez. 2014. Updated analysis of abundance and population structure of seasonal gray whales in the Pacific Northwest, 1996-2012. Final Report to National Marine Mammal Laboratory, Seattle, WA. 75 pp.

Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Calambokidis, J. 2016. Study of seasonal resident gray whales feeding strategy in N Puget Sound, WA in 2016. Contract Report for Cooperative Agreement CA-16-320 to Washington Department of Natural Resources. 13 pp.

Calambokidis, J., A. Perez, and J. Laake. 2019. Updated analysis of abundance and population structure of seasonal gray whales in the Pacific Northwest, 1996-2017. Final Report to NOAA, Seattle, WA. 72 pp.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria https://www.R-project.org/

Supplementary Description 7. 8. Gray whale migratory route

Species name: Gray whale (*Eschrichtius robustus*)

Stock or population: Eastern North Pacific

Descriptive name: Parent - Southbound & Northbound

BIA type: Migratory Route

BIA label: M-BIA1-s-b2-WC019-0abc

Transboundary across: GOA

Hierarchy: Hierarchical BIA; Parent of children abc

Importance score: 1 (Intensity: 1, Data support: 2)

Supporting notes for intensity score: We assigned an intensity score of 1 for this parent M-BIA based on the following criteria:

- o Proportion of population that uses the route: 90% or more, but may not capture a small proportion of migrating whales that are distributed farther offshore
- o Width of the route: Fairly narrow (<25 km) for most of it, but then wider at SCB (Southern California Bight), WA, and east Haida Gwaii
- o Number of months in which the route is used: 8 months (Nov-Jun)
- o 3 other migratory BIAs being delineated for ENP gray whales (Aleutians-Bering, Gulf of Alaska)
- o This BIA intends to capture all age/sex classes of migrating individuals
- o Transboundary BIA (extends to Gulf of Alaska)

Supporting notes for data support score: We assigned a data support score of 2 for the parent gray whale M-BIA for the West Coast region that encompasses both southbound and northbound migrations (spatially and temporally). A broader distribution of migrating gray whales in the SCB is well-supported by satellite tracking data (Mate & Urban-Ramirez, 2003; Urban R et al. 2021) and visual surveys (Rice & Wolman, 1971; Halpin et al. 2009; Carretta & Forney, 1993; Jefferson et al. 2014; Dohl et al. 1980). A broader corridor extending farther offshore with increasing latitude (from Central CA to Washington) is justified by several sources of information (Refs in corresponding manuscript table). Precise migratory corridors along the coast of British Columbia up to southeastern Alaska are not well known for ENP gray whales at large. Satellite tagged gray whales have been documented using inside waters east of Haida Gwaii and nearshore waters off west Vancouver Island during migration, however the majority of these whales were a part of the PCFG group and thus may not be reflective of the entire ENP population (Ford et al. 2013; Lagerquist et al. 2019; Urban R et al. 2021). These references combined span over 60 years of observations.

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Spatiotemporal variability indicator for all gray whale migratory BIAs is static as these boundaries are based on distance buffers from shore. Although there may be environmental factors that influence the spatiotemporal aspects of gray whale migratory behavior, these factors are not well described for the west coast region.

Boundary certainty: 2

Supporting notes for boundary certainty: We have intermediate confidence in the parent BIA boundary. The widths of all migratory corridors are supported by several long-term monitoring efforts, although less is known about the precise route along the coast of British Columbia through southeastern Alaska. The child BIAs described here capture high concentrations of migrating gray whales while the parent BIA captures a broader proportion of the population including those that take nearshore and offshore routes.

Months of year designation is applicable: January, February, March, April, May, June, November, December

Tagging data supporting designation (Y/N): Y

Supporting information: OSU personal communication; Mate & Urban-Ramirez, 2003; Urban R et al. 2021

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 20,986

# of years in which supporting visual data collected: 1975-2022

Supporting information: Justifications for this BIA were informed by the literature as well as by maps of sightings from a comprehensive dataset compiled by OBIS SeaMap (Halpin et al. 2009), which includes historical data (dating back to the 1970's) and contemporary data, from both scientific institutions and community science platforms (e.g., HappyWhale).

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): N

Genetic analyses conducted supporting designation (Y/N): N

What factors justify the boundary selection?: The migratory gray whale BIAs used in this assessment were taken directly from Calambokidis et al. (2015) and modified to more accurately reflect the known extent of migrating gray whales along the US West Coast and to establish transboundary connectivity between the West Coast and the Gulf of Alaska BIA regions.

The 2015 boundaries excluded some localized regions that are used by migrating gray whales; for the revised BIAs, the boundaries were modified to encompass these areas, which include Monterey Bay, the Gulf of the Farallones, and the entirety of the SCB. Several sources, including dedicated research organizations and citizen science platforms, have documented migrating gray whales within the inside waters of Monterey Bay and the Gulf of Farallones, warranting inclusion of this as a biologically important area during all migratory phases (Halpin et al. 2009 ; Mate & Urban-Ramirez, 2003). Further, visual survey and satellite tagging studies support a broad distribution of migrating gray whales throughout the SCB during all migratory phases, extending to areas such as the San Nicolas Basin and south of the Channel Islands (Jefferson et al. 2014, Dohl et al. 1980; Mate & Urban-Ramirez, 2003; CRC unpublished data; Rice & Wolman, 1971; Halpin et al. 2009; Caretta & Forney, 1993), as opposed to defined corridors within the SCB as reflected by the 2015 southbound and northbound BIA boundaries (Calambokidis et al. 2015). More specifically, the distribution of offshore migrating gray whales in the SCB peaks around 75 km from the mainland, with maximum distances from shore reaching up to 171 km for northbound migrating gray whales and 150 km for southbound migrating gray whales (Halpin et al. 2009). Therefore, all BIA boundaries in this assessment (parent and each child) were modified to include the entirety of the SCB, with the outer boundary defined by that of the established 2015 boundaries (approximately 190 km from the mainland at its widest).

The parent BIA was defined as the revised southbound BIA (corridor width of 10 km from California to Oregon, 15 m from Oregon to Washington, and 30 km along Washington outer oast; see details in Southbound - All child BIA) merged with an extension north along the west coast of British Columbia and up to the southmost extent of the Gulf of Alaska ENP gray whale migratory BIA to explicitly define the migratory connectivity between these two regions; as such, this parent BIA represents a transboundary BIA. This transboundary extension roughly follows the continental shelf off of Vancouver Island and along the west coast of Haida Gwaii, encompassing the inside waters of Haida Gwaii which migrating gray whales have been known to use (Ford et al. 2013; Lagerquist et al. 2019; Urbán R et al. 2021). Lastly, we defined the time period of this BIA as November through June to capture both northbound and southbound migrations from southeast Alaska to southern California (Rugh et al. 2001; Pike, 1962; Mate and Urban-Ramirez, 2003; Urban-R. et al. 2021; Poole, 1984; Herzing and Mate, 1984; Shelden et al. 2000).

Data sources: OBIS SeaMap gray whale sightings database (1975-2022; accessed 2022; Halpin et al. 2009); Cascadia Research Collective (1975-2020; accessed 2022); Oregon State University (personal communication, accessed 2022)

Approximate % of population that uses this area for the designated purpose (if known): 90% or more

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 3

References: Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Carretta, J.V., and K.A. Forney. 1993. Report of the two aerial surveys for marine mammals in California coastal waters utilizing a NOAA DeHavilland Twin Otter Aircraft March 9-April 7, 1991 and February 8-April 6, 1992. NOAA Technical Memorandum NMFS NOAA-TM-NMFS-SWFSC-195

Dohl, T.P., K.S. Norris, R.C. Guess, J.D. Bryant, and M.W. Honig. 1980. Cetacea of the Southern California Bight. Part II, Summary of marine mammal and seabird surveys of the Southern California Bight area, 1975-1978. Final report to the Bureau of Land Management, NTIS Rep. No. PB81248189 414 pp.

Ferguson, M.C., C. Curtice, and J. Harrison. 2015. Biologically Important Areas for Cetaceans within U.S. Waters – Gulf of Alaska Region. Aquatic Mammals 41(1): 65-78

Ford, J.K.B., J.W. Durban, G.M. Ellis, J.R. Towers, J.F. Pilkington, L.G. Barrett-Lennard, and R.D. Andrews. 2013. New insights into the northward migration route of gray whales between Vancouver Island, British Columbia, and southeastern Alaska. Marine Mammal Science 29(2): 325-337 doi:10.1111/j.1748-7692.2012.00572.x

Green, G.A., J.J. Brueggeman, R.A. Grotefendt, and C.E. Bowlby. 1995. Offshore distances of gray whales migrating along the Oregon and Washington Coasts, 1990. Northwest Science 69(3): 223-226

Halpin, P.N., A.J. Read, E. Fujioka, B.D. Best, B. Donnelly, L.J. Hazen, C. Kot, K. Urian, E. LaBrecque, A. Dimatteo, J. Cleary, C. Good, L.B. Crowder, and K.D. Hyrenbach. 2009. OBIS-SEAMP: The world data center for marine mammal, sea bird, and sea turtle distributions. Oceanography 22(2):104-115

Herzing, D.L., and B.R. Mate. 1984. Gray whale migrations along the Oregon Coast, 1978-1981. In: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The Gray Whale, Eschrichtius robustus. Pp. 289-307. Academic Press, Inc., Orlando, Florida

Jefferson, T.A., M.A. Smultea, and C.E. Bacon. 2014. Southern California Bight marine mammal density and abundance from aerial surveys, 2008-2013. Journal of Marine Animals and Their Ecology 7(2):14-30.

Lagerquist, B.L., D.M. Palacios, M.H. Winsor, L.M. Irvine, T.M. Follett, and B.R. Mate. 2019. Feeding home ranges of pacific coast feeding group gray whales. The Journal of Wildlife Management 83(4):925-937

Mate, B.R., and J. Urban-Ramirez. 2003. A note on the route and speed of a gray whale on its northern migration from Mexico to central California, tracked by satellite-monitored radio tag. Journal of Cetacean Research Management 5(2):155-157

Mate, B.R., V.Y. Ilyashenko, A.L. Bradford, V.V. Vertyankin, G.A. Tsidulko, V.V. Rozhnov, and L.M. Irvine. 2015. Critically endangered western gray whales migrate to the eastern North Pacific. Biology Letters 11:20150071 doi:10.1098/rsbl.2015.0071

Pike, G.C. 1962. Migration and feeding of the gray whale (Eschrichtius gibbosus). J. Fish. Res. Bd. Candana 19(5)

Poole, M.M. 1984. Migration corridors of gray whales along the central California coast, 1980-1982. In: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The Gray Whale, Eschrichtius robustus. Pp. 389-407. Academic Press, Inc., Orlando, Florida

Rice, D.W., and A.W. Wolman. 1971. The life history and ecology of the gray whale (Eschrichtius robustus). American Society of Mammologists, Special Publication 3. 142 pp.

Rugh, D.J., K.E.W. Shelden, and A. Schulman-Janiger. 2001. Timing of the gray whale southbound migration. Journal of Cetacean Research Management 3(1):31-39

Shelden, K.E.W., D.J. Rugh, J.L. Laake, J.M. Waite, P.J. Gearin, and T.R. Wahl. 2000. Winter observations of cetaceans off the northern Washington Coast. Northwestern Naturalist 81:54-59

Shelden, K.E.W., and J.L. Laake. 2002. Comparison of the offshore distribution of southbound migrating gray whales from aerial survey data collected off Granite Canyon, California, 1979-96. Journal of Cetacean Research and Management 4(1):53-56.

Urbán R, J., E. Jiménez-López, H.M. Guzmán, and L. Viloria-Gómora. 2021. Migratory behavior of an Eastern North Pacific gray whale from Baja California Sur to Chirikov Basin, Alaska. Frontiers in Marine Science 8:619290 doi:10.3389/fmars.2021.619290

Supplementary Description 7. 9. Gray whale migratory route

Species name: Gray whale (*Eschrichtius robustus*)

Stock or population: Eastern North Pacific

Descriptive name: Northbound - Phase B

BIA type: Migratory Route

BIA label: M-BIA3-s-b3-WC019-c

Transboundary across: None

Hierarchy: Hierarchical BIA; Child c

Importance score: 3 (Intensity: 3, Data support: 3)

Supporting notes for intensity score: We assigned an intensity score of 3 for this Northbound Phase B M-BIA based on the following metrics:

o Proportion of population that uses the route: 50-90%
o Width of the route: <25km (5 km throughout with exception to the Southern California Bight (SCB))
o Number of months in which the route is used: 3 months (March-May)
o 3 other migratory BIAs being delineated for ENP gray whales (Aleutians-Bering, Gulf of Alaska)
o This route is primarily used by cow/calf pairs that tend to migrate closer to shore than adults and juveniles
o Does not extend north to the Gulf of Alaska M-BIA

We point out that the lines of evidence supporting this BIA's Intensity score of 3 are very similar to that of the Northbound Phase A BIA, which has an Intensity score of 2. Intensity for the Northbound Phase B BIA was scored higher than that for Northbound Phase A because Phase B occupies a narrower corridor and shorter time period. In addition, Phase B reflects an important migratory corridor specifically for mother/calf pairs, a more vulnerable demographic.

Supporting notes for data support score: We assigned a data support score of 3 to this BIA. Migratory corridors defined here were taken directly from Calambokidis et al. (2015) and modified based on support from several sources of historical and contemporary information, including tagging studies (Mate and Urban-Ramirez, 2003; Lagerquist et al. 2019; OSU pers comm, 2022; Urban R et al. 2021), dedicated and opportunistic boat-, aerial-, and land-based visual surveys (Rice and Wolman, 1971; Halpin et al. 2009; Dohl et al. 1980; Rugh et al., 2001; Green et al. 1995; CRC unpublished; Poole, 1984; Herzing and Mate, 1984; Shelden and Laake, 2002; Shelden et al. 2000; Caretta and Forney, 1993; Jefferson et al. 2014). These references combined span over 60 years of observations.

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Spatiotemporal variability indicator for all gray whale migratory BIAs is static as these boundaries are based on distance buffers from shore. Although there may be environmental factors that influence the spatiotemporal aspects of gray whale migratory behavior, these factors are not well described for the west coast region.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainties for each child migratory BIA described here for gray whales off the US West Coast. The widths of all migratory corridors are supported by several long-term monitoring efforts, although less is known about the precise route along the coast of British Columbia through southeastern Alaska. The child BIAs described here capture high concentrations of migrating gray whales while the parent BIA captures a broader proportion of the population including those that take nearshore and offshore routes.

Months of year designation is applicable: March, April, May

Tagging data supporting designation (Y/N): N

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 4,896

# of years in which supporting visual data collected: 1975-2022

Supporting information: Justification for this corridor was supported by the literature as well as by maps of sightings from a comprehensive dataset compiled by OBIS SeaMap (Halpin et al. 2009), which includes historical data (dating back to the 1970's) and contemporary data, from both scientific institutions and community science platforms (e.g., HappyWhale).

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): N

Genetic analyses conducted supporting designation (Y/N): N

What factors justify the boundary selection?: The migratory gray whale BIAs used in this assessment were taken directly from Calambokidis et al. (2015) and modified to more accurately reflect the known extent of migrating gray whales along the US West Coast and to establish transboundary connectivity between the West Coast and the Gulf of Alaska BIA regions.

The 2015 boundaries excluded some localized regions that are used by migrating gray whales; for the revised BIAs, the boundaries were modified to encompass these areas, which include Monterey Bay, the Gulf of the Farallones, and the entirety of the SCB. Several sources, including dedicated research organizations and citizen science platforms, have documented migrating gray whales within the inside waters of Monterey Bay and the Gulf of Farallones, warranting inclusion of this as a biologically important area during all migratory phases (Halpin et al. 2009; Mate & Urban-Ramirez, 2003). Further, visual survey and satellite tagging studies support a broad distribution of migrating gray whales throughout the SCB during all migratory phases, extending to areas such as the San Nicolas Basin and south of the Channel Islands (Jefferson et al. 2014, Dohl et al. 1980; Mate & Urban-Ramirez, 2003; CRC unpublished data; Rice & Wolman, 1971; Halpin et al. 2009; Caretta & Forney, 1993), as opposed to defined corridors within the SCB as reflected by the 2015 southbound and northbound BIA boundaries (Calambokidis et al. 2015). More specifically, the distribution of offshore migrating gray whales in the SCB peaks around 75 km from the mainland, with maximum distances from shore reaching up to 171 km for northbound migrating gray whales and 150 km for southbound migrating gray whales (Halpin et al. 2009). Therefore, all BIA boundaries in this assessment (parent and each child) were modified to include the entirety of the SCB, with the outer boundary defined by that of the established 2015 boundaries (approximately 190 km from the mainland at its widest).

The northbound phase B BIA (primarily cow/calf pairs) described by Calambokidis et al. (2015) remained largely the same (5 km from shore corridor along the entire coast north of the SCB) with exception to the modifications that were applied to all migratory BIAs described herein (i.e., filling in Monterey Bay, Gulf of Farallones, SCB). A number of previous studies support a nearshore corridor for northbound migrating gray whale cows and calves (Poole, 1984; Halpin et al. 2009; Herzing and Mate, 1984; WDFW pers comm, 2022). While this BIA previously spanned months March through July, we redefined the time period for this corridor to March through May to more accurately reflect the time period that this phase of gray whales occurs on the US West Coast, rather than that of their entire northbound migratory route to the Arctic (Poole, 1984). This BIA is totally within the Phase A BIA but reflects the narrower corridor and more specific time period for the mother and calf portion of the migration.

Data sources: OBIS SeaMap gray whale sightings database (1975-2022; accessed 2022; Halpin et al. 2009); Cascadia Research Collective (1975-2020; accessed 2022); Oregon State University (accessed 2022)

Approximate % of population that uses this area for the designated purpose (if known): 50-90%

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 1

References: Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Carretta, J.V., and K.A. Forney. 1993. Report of the two aerial surveys for marine mammals in California coastal waters utilizing a NOAA DeHavilland Twin Otter Aircraft March 9-April 7, 1991 and February 8-April 6, 1992. NOAA Technical Memorandum NMFS NOAA-TM-NMFS-SWFSC-195

Dohl, T.P., K.S. Norris, R.C. Guess, J.D. Bryant, and M.W. Honig. 1980. Cetacea of the Southern California Bight. Part II, Summary of marine mammal and seabird surveys of the Southern California Bight area, 1975-1978. Final report to the Bureau of Land Management, NTIS Rep. No. PB81248189 414 pp.

Ferguson, M.C., C. Curtice, and J. Harrison. 2015. Biologically Important Areas for Cetaceans within U.S. Waters – Gulf of Alaska Region. Aquatic Mammals 41(1): 65-78

Ford, J.K.B., J.W. Durban, G.M. Ellis, J.R. Towers, J.F. Pilkington, L.G. Barrett-Lennard, and R.D. Andrews. 2013. New insights into the northward migration route of gray whales between Vancouver Island, British Columbia, and southeastern Alaska. Marine Mammal Science 29(2): 325-337 doi:10.1111/j.1748-7692.2012.00572.x

Green, G.A., J.J. Brueggeman, R.A. Grotefendt, and C.E. Bowlby. 1995. Offshore distances of gray whales migrating along the Oregon and Washington Coasts, 1990. Northwest Science 69(3): 223-226

Halpin, P.N., A.J. Read, E. Fujioka, B.D. Best, B. Donnelly, L.J. Hazen, C. Kot, K. Urian, E. LaBrecque, A. Dimatteo, J. Cleary, C. Good, L.B. Crowder, and K.D. Hyrenbach. 2009. OBIS-SEAMP: The world data center for marine mammal, sea bird, and sea turtle distributions. Oceanography 22(2):104-115

Herzing, D.L., and B.R. Mate. 1984. Gray whale migrations along the Oregon Coast, 1978-1981. In: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The Gray Whale, Eschrichtius robustus. Pp. 289-307. Academic Press, Inc., Orlando, Florida

Jefferson, T.A., M.A. Smultea, and C.E. Bacon. 2014. Southern California Bight marine mammal density and abundance from aerial surveys, 2008-2013. Journal of Marine Animals and Their Ecology 7(2):14-30.

Lagerquist, B.L., D.M. Palacios, M.H. Winsor, L.M. Irvine, T.M. Follett, and B.R. Mate. 2019. Feeding home ranges of pacific coast feeding group gray whales. The Journal of Wildlife Management 83(4):925-937

Mate, B.R., and J. Urban-Ramirez. 2003. A note on the route and speed of a gray whale on its northern migration from Mexico to central California, tracked by satellite-monitored radio tag. Journal of Cetacean Research Management 5(2):155-157

Mate, B.R., V.Y. Ilyashenko, A.L. Bradford, V.V. Vertyankin, G.A. Tsidulko, V.V. Rozhnov, and L.M. Irvine. 2015. Critically endangered western gray whales migrate to the eastern North Pacific. Biology Letters 11:20150071 doi:10.1098/rsbl.2015.0071

Pike, G.C. 1962. Migration and feeding of the gray whale (Eschrichtius gibbosus). J. Fish. Res. Bd. Candana 19(5)

Poole, M.M. 1984. Migration corridors of gray whales along the central California coast, 1980-1982. In: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The Gray Whale, Eschrichtius robustus. Pp. 389-407. Academic Press, Inc., Orlando, Florida

Rice, D.W., and A.W. Wolman. 1971. The life history and ecology of the gray whale (Eschrichtius robustus). American Society of Mammologists, Special Publication 3. 142 pp.

Rugh, D.J., K.E.W. Shelden, and A. Schulman-Janiger. 2001. Timing of the gray whale southbound migration. Journal of Cetacean Research Management 3(1):31-39

Shelden, K.E.W., D.J. Rugh, J.L. Laake, J.M. Waite, P.J. Gearin, and T.R. Wahl. 2000. Winter observations of cetaceans off the northern Washington Coast. Northwestern Naturalist 81:54-59

Shelden, K.E.W., and J.L. Laake. 2002. Comparison of the offshore distribution of southbound migrating gray whales from aerial survey data collected off Granite Canyon, California, 1979-96. Journal of Cetacean Research and Management 4(1):53-56.

Urbán R, J., E. Jiménez-López, H.M. Guzmán, and L. Viloria-Gómora. 2021. Migratory behavior of an Eastern North Pacific gray whale from Baja California Sur to Chirikov Basin, Alaska. Frontiers in Marine Science 8:619290 doi:10.3389/fmars.2021.619290

Supplementary Description 7. 10. Gray whale migratory route

Species name: Gray whale (*Eschrichtius robustus*)

Stock or population: Eastern North Pacific

Descriptive name: Northbound - Phase A

BIA type: Migratory Route

BIA label: M-BIA2-s-b3-WC019-b

Transboundary across: None

Hierarchy: Hierarchical BIA; Child b

Importance score: 2 (Intensity: 2, Data support: 3)

Supporting notes for intensity score: We assigned an intensity score for this Northbound Phase A M-BIA based on the following metrics:
- o Proportion of population that uses the route: 50-90%
- o Width of the route: <25km along the entire coast
- o Number of months in which the route is used: 5 months
- o 3 other migratory BIAs being delineated for ENP gray whales (Aleutians-Bering, Gulf of Alaska)
- o This BIA intends to capture all age/sex classes of migrating individuals, but primarily adults (without calves) and juveniles
- o Does not extend north to the Gulf of Alaska M-BIA

Supporting notes for data support score: We assigned a data support score of 3 for this BIA. Migratory corridors defined here were taken directly from Calambokidis et al. (2015) and modified based on support from several sources of historical and contemporary information, including tagging studies (Mate and Urban-Ramirez, 2003; Lagerquist et al. 2019; OSU pers comm, 2022; Urban R et al. 2021), dedicated and opportunistic boat-, aerial-, and land-based visual surveys (Rice and Wolman, 1971; Halpin et al. 2009; Dohl et al. 1980; Rugh et al., 2001; Green et al. 1995; CRC unpublished; Poole, 1984; Herzing and Mate, 1984; Shelden and Laake, 2002; Shelden et al. 2000; Caretta and Forney, 1993; Jefferson et al. 2014). These references combined span over 60 years of observations.

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Spatiotemporal variability indicator for all gray whale migratory BIAs is static as these boundaries are based on distance buffers from shore. Although there may be environmental factors that influence the spatiotemporal aspects of gray whale migratory behavior, these factors are not well described for the west coast region.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainties for each child migratory BIA described here for gray whales off the US West Coast. The widths of all migratory corridors are supported by several long-term monitoring efforts, although less is known about the precise route along the coast of British Columbia through southeastern Alaska. The child BIAs described here capture high concentrations of migrating gray whales while the parent BIA captures a broader proportion of the population including those that take nearshore and offshore routes.

Months of year designation is applicable: January, February, March, April, May

Tagging data supporting designation (Y/N): Y

Supporting information: OSU personal communication; Mate and Urban-Ramirez, 2003

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 19,389

# of years in which supporting visual data collected: 1975-2022

Supporting information: Modifications to this BIA were informed by the literature as well as by maps of sightings from a comprehensive dataset compiled by OBIS SeaMap (Halpin et al. 2009), which includes historical data (dating back to the 1970's) and contemporary data, from both scientific institutions and community science platforms (e.g., HappyWhale).

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): N

Genetic analyses conducted supporting designation (Y/N): N

What factors justify the boundary selection?: The migratory gray whale BIAs used in this assessment were taken directly from Calambokidis et al. (2015) and modified to more accurately reflect the known extent of migrating gray whales along the US West Coast and to establish transboundary connectivity between the West Coast and the Gulf of Alaska BIA regions.

The 2015 boundaries excluded some localized regions that are used by migrating gray whales; for the revised BIAs, the boundaries were modified to encompass these areas, which include Monterey Bay, the Gulf of the Farallones, and the entirety of the Southern California Bight (SCB). Several sources, including dedicated research organizations and citizen science platforms, have documented migrating gray whales within the inside waters of Monterey Bay and the Gulf of Farallones, warranting inclusion of this as a biologically important area during all migratory phases (Halpin et al. 2009; Mate & Urban-Ramirez, 2003). Further, visual survey and satellite tagging studies support a broad distribution of migrating gray whales throughout the SCB during all migratory phases, extending to areas such as the San Nicolas Basin and south of the Channel Islands (Jefferson et al. 2014, Dohl et al. 1980; Mate & Urban-Ramirez, 2003; CRC unpublished data; Rice & Wolman, 1971; Halpin et al. 2009; Caretta & Forney, 1993), as opposed to defined corridors within the SCB as reflected by the 2015 southbound and northbound BIA boundaries (Calambokidis et al. 2015).

More specifically, the distribution of offshore migrating gray whales in the SCB peaks around 75 km from the mainland, with maximum distances from shore reaching up to 171 km for northbound migrating gray whales and 150 km for southbound migrating gray whales (Halpin et al. 2009). Therefore, all BIA boundaries in this assessment (parent and each child) were modified to include the entirety of the SCB, with the outer boundary defined by that of the established 2015 boundaries (approximately 190 km from the mainland at its widest).

The northbound phase A BIA (primarily adults and juveniles) described by Calambokidis et al. (2015) was defined as a corridor of 8 km from shore uniformly along the US West Coast. Based on several sources and types of information, this corridor width does not appropriately depict the distribution of northbound (phase A) migrants along the entire West Coast. The 8 km distance from shore corridor is appropriate for the region north of the SCB through the remainder of California (Shelden & Laake, 2002; OSU pers comm, 2022; Poole, 1984; Mate & Urban-Ramirez, 2003; Caretta & Forney, 1993). Both aerial surveys and locations from satellite tagged gray whales indicate a slightly broader distribution off the Oregon coast (Green et al. 1995; OSU pers comm, 2022). Lastly, off the Washington coast northbound migrating gray whales have been documented just over 25 km from shore (Washington Department of Fisheries and Wildlife (WDFW) pers comm, 2022; Green et al. 1995; OSU pers comm, 2022; CRC unpublished). Based on these lines of evidence supporting variation in migratory corridor width with increasing latitude, we revised the northbound phase A BIA by expanding the corridor to 15 km from shore off the Oregon coast and 20 km from shore off the Washington coast. Lastly, the time period of this BIA was redefined as the period spanning January through May (previously January-July) to capture the vast majority of northbound (phase A) migrating gray whales within the US West Coast region (Rugh et al. 2001; Poole, 1984).

Data sources: OBIS SeaMap gray whale sightings database (1975-2022; accessed 2022; Halpin et al. 2009); Cascadia Research Collective (1975-2020; accessed 2022); Oregon State University (accessed 2022)

Approximate % of population that uses this area for the designated purpose (if known): 50-90%

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 3

References: Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Carretta, J.V., and K.A. Forney. 1993. Report of the two aerial surveys for marine mammals in California coastal waters utilizing a NOAA DeHavilland Twin Otter Aircraft March 9-April 7, 1991 and February 8-April 6, 1992. NOAA Technical Memorandum NMFS NOAA-TM-NMFS-SWFSC-195

Dohl, T.P., K.S. Norris, R.C. Guess, J.D. Bryant, and M.W. Honig. 1980. Cetacea of the Southern California Bight. Part II, Summary of marine mammal and seabird surveys of the Southern California Bight area, 1975-1978. Final report to the Bureau of Land Management, NTIS Rep. No. PB81248189 414 pp.

Ferguson, M.C., C. Curtice, and J. Harrison. 2015. Biologically Important Areas for Cetaceans within U.S. Waters – Gulf of Alaska Region. Aquatic Mammals 41(1): 65-78

Ford, J.K.B., J.W. Durban, G.M. Ellis, J.R. Towers, J.F. Pilkington, L.G. Barrett-Lennard, and R.D. Andrews. 2013. New insights into the northward migration route of gray whales between Vancouver Island, British Columbia, and southeastern Alaska. Marine Mammal Science 29(2): 325-337 doi:10.1111/j.1748-7692.2012.00572.x

Green, G.A., J.J. Brueggeman, R.A. Grotefendt, and C.E. Bowlby. 1995. Offshore distances of gray whales migrating along the Oregon and Washington Coasts, 1990. Northwest Science 69(3): 223-226

Halpin, P.N., A.J. Read, E. Fujioka, B.D. Best, B. Donnelly, L.J. Hazen, C. Kot, K. Urian, E. LaBrecque, A. Dimatteo, J. Cleary, C. Good, L.B. Crowder, and K.D. Hyrenbach. 2009. OBIS-SEAMP: The world data center for marine mammal, sea bird, and sea turtle distributions. Oceanography 22(2):104-115

Herzing, D.L., and B.R. Mate. 1984. Gray whale migrations along the Oregon Coast, 1978-1981. In: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The Gray Whale, Eschrichtius robustus. Pp. 289-307. Academic Press, Inc., Orlando, Florida

Jefferson, T.A., M.A. Smultea, and C.E. Bacon. 2014. Southern California Bight marine mammal density and abundance from aerial surveys, 2008-2013. Journal of Marine Animals and Their Ecology 7(2):14-30.

Lagerquist, B.L., D.M. Palacios, M.H. Winsor, L.M. Irvine, T.M. Follett, and B.R. Mate. 2019. Feeding home ranges of pacific coast feeding group gray whales. The Journal of Wildlife Management 83(4):925-937

Mate, B.R., and J. Urban-Ramirez. 2003. A note on the route and speed of a gray whale on its northern migration from Mexico to central California, tracked by satellite-monitored radio tag. Journal of Cetacean Research Management 5(2):155-157

Mate, B.R., V.Y. Ilyashenko, A.L. Bradford, V.V. Vertyankin, G.A. Tsidulko, V.V. Rozhnov, and L.M. Irvine. 2015. Critically endangered western gray whales migrate to the eastern North Pacific. Biology Letters 11:20150071 doi:10.1098/rsbl.2015.0071

Pike, G.C. 1962. Migration and feeding of the gray whale (Eschrichtius gibbosus). J. Fish. Res. Bd. Candana 19(5)

Poole, M.M. 1984. Migration corridors of gray whales along the central California coast, 1980-1982. In: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The Gray Whale, Eschrichtius robustus. Pp. 389-407. Academic Press, Inc., Orlando, Florida

Rice, D.W., and A.W. Wolman. 1971. The life history and ecology of the gray whale (Eschrichtius robustus). American Society of Mammologists, Special Publication 3. 142 pp.

Rugh, D.J., K.E.W. Shelden, and A. Schulman-Janiger. 2001. Timing of the gray whale southbound migration. Journal of Cetacean Research Management 3(1):31-39

Shelden, K.E.W., D.J. Rugh, J.L. Laake, J.M. Waite, P.J. Gearin, and T.R. Wahl. 2000. Winter observations of cetaceans off the northern Washington Coast. Northwestern Naturalist 81:54-59

Shelden, K.E.W., and J.L. Laake. 2002. Comparison of the offshore distribution of southbound migrating gray whales from aerial survey data collected off Granite Canyon, California, 1979-96. Journal of Cetacean Research and Management 4(1):53-56.

Urbán R, J., E. Jiménez-López, H.M. Guzmán, and L. Viloria-Gómora. 2021. Migratory behavior of an Eastern North Pacific gray whale from Baja California Sur to Chirikov Basin, Alaska. Frontiers in Marine Science 8:619290 doi:10.3389/fmars.2021.619290

Supplementary Description 7. 11. Gray whale migratory route

Species name: Gray whale (*Eschrichtius robustus*)

Stock or population: Eastern North Pacific

Descriptive name: Southbound - All

BIA type: Migratory Route

BIA label: M-BIA2-s-b3-WC019-a

Transboundary across: None

Hierarchy: Hierarchical BIA; Child a

Importance score: 2 (Intensity: 2, Data support: 3)

Supporting notes for intensity score: We assigned an intensity score of 2 for the southbound child M-BIA based on the following metrics:

o Proportion of population that uses the route: 50-90%
o Width of the route: <25km for all areas along the coast except WA (30 km wide)
o Number of months in which the route is used: 4 months
o 3 other migratory BIAs being delineated for ENP gray whales (Aleutians-Bering, Gulf of Alaska)
o This BIA intends to capture all age/sex classes of migrating individuals along the US West Coast
o Does not extend north to the Gulf of Alaska M-BIA

Supporting notes for data support score: We assigned a data support score of 3 for this BIA. Migratory corridors defined here were taken directly from Calambokidis et al. (2015) and modified based on support from several sources of historical and contemporary information, including tagging studies (Mate and Urban-Ramirez, 2003; Lagerquist et al. 2019; OSU pers comm, 2022; Urban R et al. 2021), dedicated and opportunistic boat-, aerial-, and land-based visual surveys (Rice and Wolman, 1971; Halpin et al. 2009; Dohl et al. 1980; Rugh et al., 2001; Green et al. 1995; CRC unpublished; Poole, 1984; Herzing and Mate, 1984; Shelden and Laake, 2002; Shelden et al. 2000; Caretta and Forney, 1993; Jefferson et al. 2014). These references combined span over 60 years of observations.

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Spatiotemporal variability indicator for all gray whale migratory BIAs is static as these boundaries are based on distance buffers from shore. Although there may be environmental factors that influence the spatiotemporal aspects of gray whale migratory behavior, these factors are not well described for the west coast region.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainties for each child migratory BIA described here for gray whales off the US West Coast. The widths of all migratory corridors are supported by several long-term monitoring efforts, although less is known about the precise route along the coast of British Columbia through southeastern Alaska. The child BIAs described here capture high concentrations of migrating gray whales while the parent BIA captures a broader proportion of the population including those that take nearshore and offshore routes.

Months of year designation is applicable: January, February, November, December

Tagging data supporting designation (Y/N): Y

Supporting information: OSU personal communication;

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 15,399

# of years in which supporting visual data collected: 1975-2022

Supporting information: Modifications to this BIA were informed by the literature as well as by maps of sightings from a comprehensive dataset compiled by OBIS SeaMap (Halpin et al. 2009), which includes historical data (dating back to the 1970's) and contemporary data, from both scientific institutions and community science platforms (e.g., HappyWhale).

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): N

Genetic analyses conducted supporting designation (Y/N): N

What factors justify the boundary selection?: The migratory gray whale BIAs used in this assessment were taken directly from Calambokidis et al. (2015) and modified to more accurately reflect the known extent of migrating gray whales along the US West Coast and to establish transboundary connectivity between the West Coast and the Gulf of Alaska BIA regions.

The 2015 boundaries excluded some localized regions that are used by migrating gray whales; for the revised BIAs, the boundaries were modified to encompass these areas, which include Monterey Bay, the Gulf of the Farallones, and the entirety of the Southern California Bight (SCB). Several sources, including dedicated research organizations and citizen science platforms, have documented migrating gray whales within the inside waters of Monterey Bay and the Gulf of Farallones, warranting inclusion of this as a biologically important area during all migratory phases (Halpin et al. 2009 ; Mate & Urban-Ramirez, 2003). Further, visual survey and satellite tagging studies support a broad distribution of migrating gray whales throughout the SCB during all migratory phases, extending to areas such as the San Nicolas Basin and south of the Channel Islands (Jefferson et al. 2014, Dohl et al. 1980; Mate & Urban-Ramirez, 2003; CRC unpublished data; Rice & Wolman, 1971; Halpin et al. 2009; Caretta & Forney, 1993), as opposed to defined corridors within the SCB as reflected by the 2015 southbound and northbound BIA boundaries (Calambokidis et al. 2015). More specifically, the distribution of offshore migrating gray whales in the SCB peaks around 75 km from the mainland, with maximum distances from shore reaching up to 171 km for northbound migrating gray whales and 150 km for southbound migrating gray whales (Halpin et al. 2009). Therefore, all BIA boundaries in this assessment (parent and each child) were modified to include the entirety of the SCB, with the outer boundary defined by that of the established 2015 boundaries (approximately 190 km from the mainland at its widest).

The southbound BIA boundary delineated by Calambokidis et al. (2015) was defined as a corridor extending 10 km from shore along the entire West Coast. While this corridor width may be reasonable for southbound migrating gray whales along northern and central California (Shelden & Laake, 2002; OSU pers comm, 2022), there is evidence for a broader, more offshore distribution with increasing latitude along the West Coast region. For example, off the Oregon coast southbound migrating gray whales have been documented as far as 23 km from shore during aerial surveys and were on average 12 km from shore (Green et al. 1995). Even farther offshore distributions of southbound migrating gray whales have been reported along the Washington coast; during aerial surveys, gray whales were on average 24 km from shore with a maximum distance from shore of 43 km (Green et al. 1995). Early logbook reports from offshore lightships included a sighting off Cape Flattery that was 32 km from shore (Pike, 1962). Visual surveys undertaken by CRC off the Washington coast support a similar distribution of southbound migrating gray whales, with nearly all sightings between 10-30 km from shore (maximum = 57 km; CRC unpublished). OBIS SeaMap sightings in this region also support this distribution (Halpin et al. 2009). Based on these lines of evidence, it was deemed appropriate to redefine the southbound migratory corridor along the Oregon coast to 15 km wide and the portion along the Washington coast to 30 km. Lastly, the time period of the southbound BIA was redefined as the period spanning November through February (previously October through March) to capture the majority of southbound migrating gray whales along the US West Coast region (Rugh et al. 2001; Pike, 1962; Shelden et al. 2000).

Data sources: OBIS SeaMap gray whale sightings database (1975-2022; accessed 2022; Halpin et al. 2009); Cascadia Research Collective (1975-2020; accessed 2022); Oregon State University (accessed 2022)

Approximate % of population that uses this area for the designated purpose (if known): 50-90%

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 3

References: Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Carretta, J.V., and K.A. Forney. 1993. Report of the two aerial surveys for marine mammals in California coastal waters utilizing a NOAA DeHavilland Twin Otter Aircraft March 9-April 7, 1991 and February 8-April 6, 1992. NOAA Technical Memorandum NMFS NOAA-TM-NMFS-SWFSC-195

Dohl, T.P., K.S. Norris, R.C. Guess, J.D. Bryant, and M.W. Honig. 1980. Cetacea of the Southern California Bight. Part II, Summary of marine mammal and seabird surveys of the Southern California Bight area, 1975-1978. Final report to the Bureau of Land Management, NTIS Rep. No. PB81248189 414 pp.

Ferguson, M.C., C. Curtice, and J. Harrison. 2015. Biologically Important Areas for Cetaceans within U.S. Waters – Gulf of Alaska Region. Aquatic Mammals 41(1): 65-78

Ford, J.K.B., J.W. Durban, G.M. Ellis, J.R. Towers, J.F. Pilkington, L.G. Barrett-Lennard, and R.D. Andrews. 2013. New insights into the northward migration route of gray whales between Vancouver Island, British Columbia, and southeastern Alaska. Marine Mammal Science 29(2): 325-337 doi:10.1111/j.1748-7692.2012.00572.x

Green, G.A., J.J. Brueggeman, R.A. Grotefendt, and C.E. Bowlby. 1995. Offshore distances of gray whales migrating along the Oregon and Washington Coasts, 1990. Northwest Science 69(3): 223-226

Halpin, P.N., A.J. Read, E. Fujioka, B.D. Best, B. Donnelly, L.J. Hazen, C. Kot, K. Urian, E. LaBrecque, A. Dimatteo, J. Cleary, C. Good, L.B. Crowder, and K.D. Hyrenbach. 2009. OBIS-SEAMP: The world data center for marine mammal, sea bird, and sea turtle distributions. Oceanography 22(2):104-115

Herzing, D.L., and B.R. Mate. 1984. Gray whale migrations along the Oregon Coast, 1978-1981. In: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The Gray Whale, Eschrichtius robustus. Pp. 289-307. Academic Press, Inc., Orlando, Florida

Jefferson, T.A., M.A. Smultea, and C.E. Bacon. 2014. Southern California Bight marine mammal density and abundance from aerial surveys, 2008-2013. Journal of Marine Animals and Their Ecology 7(2):14-30.

Lagerquist, B.L., D.M. Palacios, M.H. Winsor, L.M. Irvine, T.M. Follett, and B.R. Mate. 2019. Feeding home ranges of pacific coast feeding group gray whales. The Journal of Wildlife Management 83(4):925-937

Mate, B.R., and J. Urban-Ramirez. 2003. A note on the route and speed of a gray whale on its northern migration from Mexico to central California, tracked by satellite-monitored radio tag. Journal of Cetacean Research Management 5(2):155-157

Mate, B.R., V.Y. Ilyashenko, A.L. Bradford, V.V. Vertyankin, G.A. Tsidulko, V.V. Rozhnov, and L.M. Irvine. 2015. Critically endangered western gray whales migrate to the eastern North Pacific. Biology Letters 11:20150071 doi:10.1098/rsbl.2015.0071

Pike, G.C. 1962. Migration and feeding of the gray whale (Eschrichtius gibbosus). J. Fish. Res. Bd. Candana 19(5)

Poole, M.M. 1984. Migration corridors of gray whales along the central California coast, 1980-1982. In: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The Gray Whale, Eschrichtius robustus. Pp. 389-407. Academic Press, Inc., Orlando, Florida

Rice, D.W., and A.W. Wolman. 1971. The life history and ecology of the gray whale (Eschrichtius robustus). American Society of Mammologists, Special Publication 3. 142 pp.

Rugh, D.J., K.E.W. Shelden, and A. Schulman-Janiger. 2001. Timing of the gray whale southbound migration. Journal of Cetacean Research Management 3(1):31-39

Shelden, K.E.W., D.J. Rugh, J.L. Laake, J.M. Waite, P.J. Gearin, and T.R. Wahl. 2000. Winter observations of cetaceans off the northern Washington Coast. Northwestern Naturalist 81:54-59

Shelden, K.E.W., and J.L. Laake. 2002. Comparison of the offshore distribution of southbound migrating gray whales from aerial survey data collected off Granite Canyon, California, 1979-96. Journal of Cetacean Research and Management 4(1):53-56.

Urbán R, J., E. Jiménez-López, H.M. Guzmán, and L. Viloria-Gómora. 2021. Migratory behavior of an Eastern North Pacific gray whale from Baja California Sur to Chirikov Basin, Alaska. Frontiers in Marine Science 8:619290 doi:10.3389/fmars.2021.619290

Supplementary Description 7. 12. Gray whale reproductive area

Species name: Gray whale (*Eschrichtius robustus*)

Stock or population: Eastern North Pacific

Descriptive name: Gray whale - cow and calf migrants

BIA type: Reproductive Area

BIA label: R-BIA3-s-b3-WC035-0

Transboundary across: None

Hierarchy: Non-hierarchical; single BIA

Importance score: 3 (Intensity: 3, Data support: 3)

Supporting notes for intensity score: We assigned an intensity score of 3 for this gray whale cow/calf migrant R-BIA based on the following metrics:
o Proportion of population that uses the route: 50-90%
o Narrow corridor width close to shore <25km (5 km throughout with exception to the Southern California Bight (SCB))
o Number of months in which the route is used: 3 months (March-May)
o Two other R-BIAs for gray whales in the Arctic
o This route is primarily used by cow/calf pairs that tend to migrate closer to shore than adults and juveniles

We point out that the lines of evidence supporting this BIA's Intensity score of 3 are very similar to that of the Northbound Phase A BIA, which has an Intensity score of 2. Intensity for the Northbound Phase B BIA was scored higher than that for Northbound Phase A because Phase B occupies a narrower corridor and shorter time period. In addition, Phase B reflects an important migratory corridor specifically for mother/calf pairs, a more vulnerable demographic.

Supporting notes for data support score: We assigned a data support score of 3 to this BIA. This R-BIA is delineated based on a migratory corridor that is disproportionately used by cow/calf pairs, and was taken directly from Calambokidis et al. (2015) and modified based on support from several sources of historical and contemporary information, including tagging studies (Mate and Urban-Ramirez, 2003; Lagerquist et al. 2019; OSU pers comm, 2022; Urban R et al. 2021), dedicated and opportunistic boat-, aerial-, and land-based visual surveys (Rice and Wolman, 1971; Halpin et al. 2009; Dohl et al. 1980; Rugh et al., 2001; Green et al. 1995; CRC unpublished; Poole, 1984; Herzing and Mate, 1984; Shelden and Laake, 2002; Shelden et al. 2000; Caretta and Forney, 1993; Jefferson et al. 2014). These references combined span over 60 years of observations.

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Spatiotemporal variability indicator for this R-BIA is static as this boundary ais based on a distance buffer from shore. Although there may be environmental factors that influence the spatiotemporal aspects of gray whale migratory behavior, these factors are not well described for the west coast region.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainties for the BIA described here for gray whales off the US West Coast. The width of this corridor used by mom/calf pairs is supported by several long-term monitoring efforts.

Months of year designation is applicable: March, April, May

Tagging data supporting designation (Y/N): N

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 4,896

# of years in which supporting visual data collected: 1975-2022

Supporting information: Justification for this corridor was supported by the literature as well as by maps of sightings from a comprehensive dataset compiled by OBIS SeaMap (Halpin et al. 2009), which includes historical data (dating back to the 1970's) and contemporary data, from both scientific institutions and community science platforms (e.g., HappyWhale).

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): N

Genetic analyses conducted supporting designation (Y/N): N

What factors justify the boundary selection?: Calambokidis et al. (2015) did not delineate a reproductive BIA for gray whales; we delineated an R-BIA in this assessment for the specific nearshore migratory corridor used late in the northbound migration disproportionally by mothers and calves. This R-BIA is the exact same boundary as the Northbound Phase B M-BIA for gray whales, which was modified as detailed below.

The 2015 boundaries excluded some localized regions that are used by migrating gray whales; for the revised BIAs, the boundaries were modified to encompass these areas, which include Monterey Bay, the Gulf of the Farallones, and the entirety of the SCB. Several sources, including dedicated research organizations and citizen science platforms, have documented migrating gray whales within the inside waters of Monterey Bay and the Gulf of Farallones, warranting inclusion of this as a biologically important area during all migratory phases (Halpin et al. 2009; Mate & Urban-Ramirez, 2003). Further, visual survey and satellite tagging studies support a broad distribution of migrating gray whales throughout the SCB during all migratory phases, extending to areas such as the San Nicolas Basin and south of the Channel Islands (Jefferson et al. 2014, Dohl et al. 1980; Mate & Urban-Ramirez, 2003; CRC unpublished data; Rice & Wolman, 1971; Halpin et al. 2009; Caretta & Forney, 1993), as opposed to defined corridors within the SCB as reflected by the 2015 southbound and northbound BIA boundaries (Calambokidis et al. 2015). More specifically, the distribution of offshore migrating gray whales in the SCB peaks around 75 km from the mainland, with maximum distances from shore reaching up to 171 km for northbound migrating gray whales and 150 km for southbound migrating gray whales (Halpin et al. 2009). Therefore, all BIA boundaries in this assessment (parent and each child) were modified to include the entirety of the SCB, with the outer boundary defined by that of the established 2015 boundaries (approximately 190 km from the mainland at its widest).

The northbound phase B BIA (primarily cow/calf pairs; also designated as an R-BIA here) described by Calambokidis et al. (2015) remained largely the same (5 km from shore corridor along the entire coast north of the SCB) with exception to the modifications that were applied to all migratory BIAs described herein (i.e., filling in Monterey Bay, Gulf of Farallones, SCB). A number of previous studies support a nearshore corridor for northbound migrating gray whale cows and calves (Poole, 1984; Halpin et al. 2009; Herzing and Mate, 1984; WDFW pers comm, 2022). While this BIA previously spanned months March through July, we redefined the time period for this corridor to March through May to more accurately reflect the time period that this phase of gray whales occurs on the US West Coast, rather than that of their entire northbound migratory route to the Arctic (Poole, 1984). This BIA reflects the narrower corridor and more specific time period for the mother and calf portion of the migration and thus meets both definitions of M-BIA and R-BIA.

Data sources: OBIS SeaMap gray whale sightings database (1975-2022; accessed 2022; Halpin et al. 2009); Cascadia Research Collective (1975-2020; accessed 2022); Oregon State University (accessed 2022)

Approximate % of population that uses this area for the designated purpose (if known): 50-90%

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 2

References: Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Carretta, J.V., and K.A. Forney. 1993. Report of the two aerial surveys for marine mammals in California coastal waters utilizing a NOAA DeHavilland Twin Otter Aircraft March 9-April 7, 1991 and February 8-April 6, 1992. NOAA Technical Memorandum NMFS NOAA-TM-NMFS-SWFSC-195

Dohl, T.P., K.S. Norris, R.C. Guess, J.D. Bryant, and M.W. Honig. 1980. Cetacea of the Southern California Bight. Part II, Summary of marine mammal and seabird surveys of the Southern California Bight area, 1975-1978. Final report to the Bureau of Land Management, NTIS Rep. No. PB81248189 414 pp.

Ferguson, M.C., C. Curtice, and J. Harrison. 2015. Biologically Important Areas for Cetaceans within U.S. Waters – Gulf of Alaska Region. Aquatic Mammals 41(1): 65-78

Ford, J.K.B., J.W. Durban, G.M. Ellis, J.R. Towers, J.F. Pilkington, L.G. Barrett-Lennard, and R.D. Andrews. 2013. New insights into the northward migration route of gray whales between Vancouver Island, British Columbia, and southeastern Alaska. Marine Mammal Science 29(2): 325-337 doi:10.1111/j.1748-7692.2012.00572.x

Green, G.A., J.J. Brueggeman, R.A. Grotefendt, and C.E. Bowlby. 1995. Offshore distances of gray whales migrating along the Oregon and Washington Coasts, 1990. Northwest Science 69(3): 223-226

Halpin, P.N., A.J. Read, E. Fujioka, B.D. Best, B. Donnelly, L.J. Hazen, C. Kot, K. Urian, E. LaBrecque, A. Dimatteo, J. Cleary, C. Good, L.B. Crowder, and K.D. Hyrenbach. 2009. OBIS-SEAMP: The world data center for marine mammal, sea bird, and sea turtle distributions. Oceanography 22(2):104-115

Herzing, D.L., and B.R. Mate. 1984. Gray whale migrations along the Oregon Coast, 1978-1981. In: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The Gray Whale, Eschrichtius robustus. Pp. 289-307. Academic Press, Inc., Orlando, Florida

Jefferson, T.A., M.A. Smultea, and C.E. Bacon. 2014. Southern California Bight marine mammal density and abundance from aerial surveys, 2008-2013. Journal of Marine Animals and Their Ecology 7(2):14-30.

Lagerquist, B.L., D.M. Palacios, M.H. Winsor, L.M. Irvine, T.M. Follett, and B.R. Mate. 2019. Feeding home ranges of pacific coast feeding group gray whales. The Journal of Wildlife Management 83(4):925-937

Mate, B.R., and J. Urban-Ramirez. 2003. A note on the route and speed of a gray whale on its northern migration from Mexico to central California, tracked by satellite-monitored radio tag. Journal of Cetacean Research Management 5(2):155-157

Mate, B.R., V.Y. Ilyashenko, A.L. Bradford, V.V. Vertyankin, G.A. Tsidulko, V.V. Rozhnov, and L.M. Irvine. 2015. Critically endangered western gray whales migrate to the eastern North Pacific. Biology Letters 11:20150071 doi:10.1098/rsbl.2015.0071

Pike, G.C. 1962. Migration and feeding of the gray whale (Eschrichtius gibbosus). J. Fish. Res. Bd. Candana 19(5)

Poole, M.M. 1984. Migration corridors of gray whales along the central California coast, 1980-1982. In: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The Gray Whale, Eschrichtius robustus. Pp. 389-407. Academic Press, Inc., Orlando, Florida

Rice, D.W., and A.W. Wolman. 1971. The life history and ecology of the gray whale (Eschrichtius robustus). American Society of

Mammologists, Special Publication 3. 142 pp.

Rugh, D.J., K.E.W. Shelden, and A. Schulman-Janiger. 2001. Timing of the gray whale southbound migration. Journal of Cetacean Research Management 3(1):31-39

Shelden, K.E.W., D.J. Rugh, J.L. Laake, J.M. Waite, P.J. Gearin, and T.R. Wahl. 2000. Winter observations of cetaceans off the northern Washington Coast. Northwestern Naturalist 81:54-59

Shelden, K.E.W., and J.L. Laake. 2002. Comparison of the offshore distribution of southbound migrating gray whales from aerial survey data collected off Granite Canyon, California, 1979-96. Journal of Cetacean Research and Management 4(1):53-56.

Urbán R, J., E. Jiménez-López, H.M. Guzmán, and L. Viloria-Gómora. 2021. Migratory behavior of an Eastern North Pacific gray whale from Baja California Sur to Chirikov Basin, Alaska. Frontiers in Marine Science 8:619290 doi:10.3389/fmars.2021.619290

Supplementary Description 7. 13. Harbor porpoise small and resident pop.

Species name: Harbor porpoise (*Phocoena phocoena*)

Stock or population: Monterey Bay

Descriptive name: Monterey Bay

BIA type: Small and Resident Pop.

BIA label: S-BIA2-s-b3-WC027-0

Transboundary across: None

Hierarchy: Non-hierarchical; single BIA

Importance score: 2 (Intensity: 2, Data support: 3)

Intensity matrix: Abundance: 1, Range: 3

Supporting notes for intensity score: Overall intensity score = 2

- Abundance estimates were reported in Forney et al., (2019) at 3,455 individuals (CV = 0.579) for 2013 (from 1986-2013) based on long-term aerial survey data. Estimates used to inform the scoring exceed the largest bin size (greater than 2,000 individuals), but coefficient of variation values associated with estimates are relatively large and thus the true population sizes may be smaller. Therefore, the abundance score = 1
- Geographic ranges are relatively large but several lines of evidence suggest there is limited movement outside of these ranges
- Findings from previous studies indicate higher densities of harbor porpoise from shore to the 92 m isobath (Forney et al., 1991; Carretta et al., 2001, 2009).
- Only two S-BIAs is being delineated for harbor porpoise in the Eastern North Pacific, one each in Monterey and Morro Bay The range size for this BIA is 1,911 km2 (range size score = 3)

Supporting notes for data support score: We assigned a Data Support score of 3 based on the following lines of supporting evidence:

- Strong evidence for genetic differentiation from harbor porpoise in other regions along the west coast (Chivers et al., 2002, 2007; Morin et al., 2021) and evidence from genetic studies supporting restricted individual dispersal along the west coast (Morin et al., 2021)
- Recent and more robust abundance estimates used to inform intensity criteria with an indication of increasing population trend for this population (Forney et al., 2019)
- Differences in pollutant residues between populations further support distinction of populations and restricted range sizes (Calambokidis and Barlow, 1991)
- Long-term aerial surveys support the range boundaries (from land to 200 m isobath)
- Radiotelemetry data from harbor porpoise provide evidence for limited movements (Hanson, 2007), albeit were from harbor porpoise in Washington inland waters

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Boundary largely defined by bathymetric contour and there is no information to suggest the area is used dynamically or ephemerally.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainty for the Monterey Bay harbor porpoise S-BIA, based on the longevity, quantity, and quality of available supporting information. Although limited information on detailed movements of harbor porpoise are available (Hanson, 2007), a variety of other supporting lines of evidence indicate that these populations are generally restricted to the 200-m isobath with higher concentrations inside the 100 m isobath, and that movements outside of these ranges are unlikely to occur.

Months of year designation is applicable: Year-round

Tagging data supporting designation (Y/N): N

Visual observations/records supporting designation (Y/N): Y

# of years in which supporting visual data collected: Greater than 15 y

Supporting information: Extensive aerial line-transect surveys and habitat-based density estimates show lowest densities in outer periphery of population range and that they do not generally go beyond 200-m isobath (Forney et al., 1991; Carretta et al., 2001, 2009)

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): N

Genetic analyses conducted supporting designation (Y/N): Y

Weak/moderate/strong support for genetic differentiation: Strong

Nature of supporting information: Strong

Supporting information: Genetic analysis (mtDNA and nuclear DNA) of samples collected along the West Coast between 1984 and 2005 indicate population is genetically distinct and geographically isolated in the Pacific. See also Morin et al. (2021)

What factors justify the boundary selection?: Calambokidis et al., (2015) delineated a small and resident BIA for the Monterey Bay harbor porpoise stock off the West Coast based on the recognized stock boundary and the BIA here is taken directly from that boundary. Several lines of evidence suggest this stock has a restricted range, including regional differences in pollutant ratios (Calambokidis and Barlow, 1991), genetic studies (Chivers et al., 2002, 2007), and densities derived from aerial surveys (Forney et al., 1991; Forney, 1995, 1999; Caretta et al., 2009). Boundaries were defined using the 200 m isobath from land (Monterey Bay = Point Sur to Pigeon Point).

Although the spatial boundary remained the same, information from previous and more recent studies were used to support the scoring. Contemporary abundance estimates from each respective stock assessment report (Carretta et al., 2022) were used in combination with the area of the BIA to determine the Intensity scores through the S-BIA scoring matrix.

Approximate % of population that uses this area for the designated purpose (if known): 100

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 1

References: Forney et al., 1991, 2019; Forney, 1995; Caretta et al., 2009; Morin et al., 2021; Chivers et al., 2002, 2007

Calambokidis, J., and J. Barlow. 1991. Chlorinated hydrocarbon concentrations and their use for describing population discreteness in harbor porpoises from Washington, Oregon, and California. Pp. 101-110 In: J.E. Reynolds III and D.K. Odell (eds.) Marine mammal strandings in the United States. NOAA Techincal Report NMFS 98

Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Carretta, J.V., B.L. Taylor, and S.J. Chivers. 2001. Abundance and depth distribution of harbor porpoise (Phocoena phocoena) in northern California determined from a 1995 ship survey. U.S. Fishery Bulletin 99:29-39

Chivers, S.J., A.E. Dizon, P.J. Gearin, and K.M. Roberston. 2002. Small-scale population structure of eastern North Pacific harbour porpoises, (Phocoena phocoena), indicated by molecular genetic analyses. Journal of Cetacean Research and Management 4(2):111-122

Chivers, S.J., B. Hanson, J. Laake, P. Gearin, M.M. Muto, J. Calambokidis, D. Duffield, T. McGuire, J. Hodder, D. Greig, E. Wheeler, J. Harvey, K.M. Robertson, and B. Hancock. 2007. Additional genetic evidence for population structure of Phocoena phocoena off the coasts of California, Oregon, and Washington. Southwest Fisheries Science Center Administrative Report LJ-07-08 16 pp.

Forney, K.A., J.E. Moore, J. Barlow, J.V. Caretta, and S.R. Benson. 2019. A multi-decadal Bayesian trend analysis of harbor porpoise (Phocoena phocoena) populations off California relative to past fishery bycatch. Marine Mammal Science 37(2):546-560

Hanson, M.B. 2007. Using location data from telemetry tagged marine mammals to improve stock assessments. In P. Sheridan, J.W. Ferguson, and S.L. Downing (eds.), Report of the National Marine Fisheries Service Workshop on Advancing Electronic Tag Technology and Their Use in Stock Assessments. U.S. Department of Commerce, NOAA Technical Memorandum NMFSF/SPO-82, 82.

Morin, P.A., B.R. Forester, K.A. Forney, C.A. Crossman, G.L. Hancock-Hanser, K.M. Robertson, L.G. Barrett-Lennard, R.W. Baird, J. Calambokidis, P. Gearin, M.B. Hanson, C. Schumacher, T. Harkins, M.C. Fontaine, B.L. Taylor, and K.M. Parsons. 2021. Population structure in a continuously distributed coastal marine species, the harbor porpoise, based on microhaplotypes derived from poor-quality samples. Molecular Ecology 30(6):1457-1476

Supplementary Description 7. 14. Harbor porpoise small and resident pop.

Species name: Harbor porpoise (*Phocoena phocoena*)

Stock or population: Morro Bay

Descriptive name: Morro Bay

BIA type: Small and Resident Pop.

BIA label: S-BIA1-s-b3-WC028-0

Transboundary across: None

Hierarchy: Non-hierarchical; single BIA

Importance score: 1 (Intensity: 1, Data support: 3)

Intensity matrix: Abundance: 1, Range: 2

Supporting notes for intensity score: Overall intensity score = 1

• Abundance estimates were more recently provided by Forney et al., (2019) at 4,255 individuals (CV=0.562) estimated for 2012 (from 1986-2012), based on long-term aerial surveys. These estimates used to inform the scoring exceed the largest bin size (greater than 2,000 individuals), but coefficient of variation values associated with estimates are relatively large and thus the true population sizes may be smaller. (abundance score = 1)

• Geographic ranges are relatively large but several lines of evidence suggest there is limited movement outside of these ranges

• Findings from previous studies indicate higher densities of harbor porpoise from shore to the 92 m isobath (Forney et al., 1991; Carretta et al., 2001, 2009).

• Only two S-BIAs are being delineated for harbor porpoise in the Eastern North Pacific, one each in Monterey and Morro Bay.

The range size of this BIA is 3,030 km2 (range size score = 2)

Supporting notes for data support score: We assigned a Data Support score of 3 for this BIA based on the following lines of supporting evidence:

• Strong evidence for genetic differentiation from harbor porpoise in other regions along the west coast (Chivers et al., 2002, 2007; Morin et al., 2021) and evidence from genetic studies supporting restricted individual dispersal along the west coast (Morin et al., 2021)

• Recent and more robust abundance estimates used to inform intensity criteria with an indication of increasing population trend for this population (Forney et al., 2019)

• Differences in pollutant residues between populations further support distinction of populations and restricted range sizes (Calambokidis and Barlow, 1991)

• Long-term aerial surveys support the range boundaries (from land to 200 m isobath)

• Radiotelemetry data from harbor porpoise provide evidence for limited movements (Hanson, 2007), albeit were from harbor porpoise in Washington inland waters

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Boundary largely based on bathymetric contour and there is no information to suggest the area is used dynamically.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainty for the Morro Bay harbor porpoise S-BIA, based on the longevity, quantity, and quality of available supporting information. Although limited information on detailed movements of harbor porpoise are available (Hanson, 2007), a variety of other supporting lines of evidence indicate that these populations are generally restricted to the 200-m isobath with higher concentrations inside the 100-m isobath, and that movements outside of these ranges are unlikely to occur.

Months of year designation is applicable: Year-round

Tagging data supporting designation (Y/N): N

Visual observations/records supporting designation (Y/N): Y

# of years in which supporting visual data collected: Greater than 15 y

Supporting information: Extensive aerial line-transect surveys and habitat-based density estimates show lowest densities in outer periphery of population range and that they do not generally go beyond 200-m isobath (Forney et al., 1991; Carretta et al., 2001, 2009).

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): N

Genetic analyses conducted supporting designation (Y/N): Y

Weak/moderate/strong support for genetic differentiation: Strong

Nature of supporting information: Strong

Supporting information: Genetic analysis (mtDNA and nuclear DNA) of samples collected along the West Coast between 1984 and 2005 indicate population is genetically distinct and geographically isolated. See also Morin et al. (2021)

What factors justify the boundary selection?: Calambokidis et al., (2015) delineated a small and resident BIA for the Morro Bay harbor porpoise stock off the west coast based on the recognized stock boundary and the BIA here is taken directly from that boundary. Several lines of evidence suggest that this stock has a restricted range, including regional differences in pollutant ratios

(Calambokidis and Barlow, 1991), genetic studies (Chivers et al., 2002, 2007), and densities derived from aerial surveys (Forney et al., 1991; Forney, 1995, 1999; Caretta et al., 2009). Boundaries were defined using the 200 m isobath from land for each stock boundary (Morro Bay = Point Conception to Point Sur).

Although the spatial boundary remained the same, information from previous and more recent studies were used to support the scoring (Table 1, Supplementary File B). Contemporary abundance estimates from each respective stock assessment report (Carretta et al., 2022) were used in combination with the area of the BIA to determine the Intensity scores through the S-BIA scoring matrix.

Approximate % of population that uses this area for the designated purpose (if known): 100

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 1

References: Forney et al., 1991, 2019; Forney, 1995, 1999; Carretta et al., 2009; Morin et al., 2021; Chivers et al., 2002, 2007;

Calambokidis, J., and J. Barlow. 1991. Chlorinated hydrocarbon concentrations and their use for describing population discreteness in harbor porpoises from Washington, Oregon, and California. Pp. 101-110 In: J.E. Reynolds III and D.K. Odell (eds.) Marine mammal strandings in the United States. NOAA Techincal Report NMFS 98

Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Carretta, J.V., B.L. Taylor, and S.J. Chivers. 2001. Abundance and depth distribution of harbor porpoise (Phocoena phocoena) in northern California determined from a 1995 ship survey. U.S. Fishery Bulletin 99:29-39

Chivers, S.J., A.E. Dizon, P.J. Gearin, and K.M. Roberston. 2002. Small-scale population structure of eastern North Pacific harbour porpoises, (Phocoena phocoena), indicated by molecular genetic analyses. Journal of Cetacean Research and Management 4(2):111-122

Chivers, S.J., B. Hanson, J. Laake, P. Gearin, M.M. Muto, J. Calambokidis, D. Duffield, T. McGuire, J. Hodder, D. Greig, E. Wheeler, J. Harvey, K.M. Robertson, and B. Hancock. 2007. Additional genetic evidence for population structure of Phocoena phocoena off the coasts of California, Oregon, and Washington. Southwest Fisheries Science Center Administrative Report LJ-07-08 16 pp.

Forney, K.A., J.E. Moore, J. Barlow, J.V. Caretta, and S.R. Benson. 2019. A multi-decadal Bayesian trend analysis of harbor porpoise (Phocoena phocoena) populations off California relative to past fishery bycatch. Marine Mammal Science 37(2):546-560

Hanson, M.B. 2007. Using location data from telemetry tagged marine mammals to improve stock assessments. In P. Sheridan, J.W. Ferguson, and S.L. Downing (eds.), Report of the National Marine Fisheries Service Workshop on Advancing Electronic Tag Technology and Their Use in Stock Assessments. U.S. Department of Commerce, NOAA Technical Memorandum NMFSF/SPO-82, 82.

Morin, P.A., B.R. Forester, K.A. Forney, C.A. Crossman, G.L. Hancock-Hanser, K.M. Robertson, L.G. Barrett-Lennard, R.W. Baird, J. Calambokidis, P. Gearin, M.B. Hanson, C. Schumacher, T. Harkins, M.C. Fontaine, B.L. Taylor, and K.M. Parsons. 2021. Population structure in a continuously distributed coastal marine species, the harbor porpoise, based on microhaplotypes derived from poor-quality samples. Molecular Ecology 30(6):1457-1476

Supplementary Description 7. 15. Humpback whale feeding area

Species name: Humpback whale (*Megaptera novaeangliae*)

Descriptive name: Humpback whale West Coast - Parent

BIA type: Feeding Area

BIA label: F-BIA2-s-b3-WC030-0a

Transboundary across: None

Hierarchy: Hierarchical BIA; Parent of children a

Importance score: 2 (Intensity: 2, Data support: 3)

Supporting notes for intensity score: We assigned an Intensity score of 2 for this BIA due to the following reasons:

- Humpback whales make extensive movements between low- latitude breeding grounds off Mexico and Central America to productive, high- latitude feeding grounds off the US West Coast, as characterized by this revised BIA.
- California/Oregon feeding humpback whales were recently estimated at 4,973 (SE=239) individuals (Calambokidis and Barlow, 2020) with a positive population growth trend over recent decades. Abundance of feeding humpback whales off Washington/southern British Columbia has also increased rapidly and are is estimated at 1,593 (SE=108) individuals (Calambokidis and Barlow, 2020); this rapid growth rate highlights the emerging importance of this region as a feeding ground for humpback whales migrating from low- latitude regions. The entire North Pacific population of humpback whales was estimated at around 20,000 individuals (Barlow et al. 2011, Wade 2017, Calambokidis et al. 2008), indicating the BIA described here represents a significant feeding area for humpback whales in the North Pacific.
- Humpback whales can be found off the US West Coast throughout the year although concentrations begin to increase in spring, peak in the summer and fall, and decrease in the late fall into winter. This seasonal occurrence aligns with seasonal prey availability along the US West Coast and the feeding BIA described here captures the spring to late fall period (March through November).
- HD model predicted density threshold value chosen for the BIA boundary determination process includes highest whale densities predicted for the study area.
- Although other feeding BIAs are being delineated for humpback whales in the North Pacific (e.g., Gulf of Alaska), individual humpbacks feeding off the US West Coast exhibit high site fidelity to particular feeding areas within the broader West Coast region and are unlikely to use other feeding BIAs delineated in the North Pacific .

Supporting notes for data support score: We assigned a Data Support score of 3 for this BIA due to the following lines of supporting evidence:

- This revised feeding BIA boundaries and corresponding time period were informed by additional sightings collected since the 2015 effort, spanning 34 years in total (1986-2020), and restricted to those where feeding or milling behaviors were observed.
- The addition of home ranges derived from 41 satellite tagged humpback whales from 2004-2019 provided a more unbiased (relative to dedicated survey efforts) perspective on the distribution of these whales feeding off the US West Coast. Satellite tag locations used to derive feeding home ranges were informed by movement model estimated behaviors (i.e., area-restricted search; Palacios et al., 2020).
- Although nearly half of the satellite tags included in this assessment were deployed off the Washington/Pacific Northwest coast, individuals tagged here generally remained within the Swiftsure Bank/Strait of Juan de Fuca regions ranging from 30 to 121 days in total, further supporting site fidelity to regional-specific feeding grounds and increasing importance of Washington/southern British Columbia as a feeding ground for humpback whales; these grounds are highlighted by the child (core) BIA.
- High- resolution, short-term tracks of tagged humpback whales feeding off of Washington reported by Schorr et al., (2013) further support the importance of the Washington/southern British Columbia feeding grounds.
- Habitat-based density models used represent multi-year averages (spanning 1991-2018) of predictions during the summer/fall feeding season reflecting a broader distribution for the BIAs, and account for documented increases in humpback whale numbers in the study area over the study period (Becker et al., 2020b). Predicted densities agree with concentrations of both sightings of feeding/milling humpback whales and overlap of individual feeding humpback whale home ranges derived from satellite tag data.
- Abundance estimates specific to this region are contemporary and based on long-term sighting and photographic data (Calambokidis and Barlow, 2020).
- Child (core) BIA highlights feeding “hotspots” within the broader parent BIA boundary agreed among higher levels of each supporting data layer (concentrations of sightings, increased home range overlap from satellite tagged whales, higher habitat-based density model predictions).

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Spatiotemporal variability indicator for both parent and core humpback whale F-BIAs is static. Large whales (such as humpbacks) may respond to spatiotemporal variation in the environment and some of the habitat models for large whales have incorporated dynamic variables to try and predict this (Forney et al. 2012, Becker et al 2020a. 2020b, Abrahms et al. 2019a, 2019b). More specifically, common variation in oceanographic conditions along the West Coast region often results in variation in the spatial distribution of large whale prey patches (e.g., krill, anchovies). As such, these whales may adjust their feeding behavior in space and time accordingly. However, we assigned a Spatiotemporal Variability Indicator score of “static” for all BIAs here, due to the following reasons: (1) for BIAs derived from the integrated approach (such as this one), we intentionally attempted to account for year-to-year variability in whale distribution by using multi-year averaged HD model outputs; (2) many of the BIAs’ spatial extents cover large areas, such that whale distribution within those areas may change in response to the environment, but the spatial polygons themselves are unlikely to move in space or time.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainty for both the parent and child humpback whale feeding BIAs described in this assessment, although see narrative on spatiotemporal variability above. This boundary is supported by three independent data sources (sightings from small-boat surveys, home ranges from long-term satellite tag deployments, multi-year averaged habitat-based density models) and combined have complementary strengths and weaknesses. The parent BIA boundary characterized here encompasses (1) nearly all visual sightings of feeding or milling humpback whales documented from 1986 through 2020; (2) the majority of shared home ranges from satellite tagged humpback whales; and (3) broad levels of predicted densities from HD models along the coastline. The resulting parent BIA corresponds well with the bathymetric features typically used by humpback whales feeding on prey aggregations during the March-November feeding season . The resulting child BIA reflects higher intensity values of all three supporting data layers, highlighting both known (e.g., Monterey Bay, Gulf of Farallones) and recently emerging (e.g., Swiftsure Bank) important primary feeding grounds for humpback whales within the broader coast-wide West Coast feeding ground.

Months of year designation is applicable: March, April, May, June, July, August, September, October, November

Tagging data supporting designation (Y/N): Y

# of tags: 41

# of years in which supporting tagging data collected: 5 (2004-2019)

Supporting information: Home ranges (HR) were estimated for forty-one humpback whales satellite-tagged by OSU along the west coast from 2004 through 2019. HRs were estimated for individual tagged whales using kernel density estimation methods as described in Palacios et al. (2020); details on satellite tag data processing methods are provided as supplementary material (see manuscript materials). We quantified intensity of space use by mapping each individual's home range on a 10 km x 10 km raster (all on the same grid), summing the total number of home ranges in each cell across all individuals, and calculating the proportion of the total 41 home ranges within each grid cell. For the parent BIA, we chose a proportion of all home ranges based on a threshold value of 0.025 (i.e., grid cells with greater than 0.025 proportion of all home ranges included). For the child BIA, a threshold value of 0.075 proportion of the total 41 home ranges was chosen.

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 4777

# of years in which supporting visual data collected: 34 (1986-2020)

Supporting information: Sightings data used for the BIA boundary determinations were collected from dedicated small boat survey efforts conducted by CRC from 1986 through 2020; only sightings where feeding or milling behaviors were observed were included in this assessment (n=4,777). To create a layer based on this dataset, we used kernel density estimation (KDE) to generate a two-dimensional probability distribution using the package ks (Duong, 2021). The bandwidth value (smoothing parameter) was set to 10 kilometers . For the parent BIA, a broad KDE contour threshold of at least 90% was chosen. For the child BIA, a narrower KDE contour threshold of 80% was chosen.

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): Y

Supporting information: Calambokidis et al. 2008

Genetic analyses conducted supporting designation (Y/N): Y

Nature of supporting information: Strong

Supporting information: Baker et al. 2008, 2013

What factors justify the boundary selection?: A combination of sightings data collected from dedicated small boat survey efforts by Cascadia Research Collective (CRC), satellite tag data from long-term implant tags deployed by Oregon State University (OSU), and multi-year averaged habitat-based density (HD) models generated by Southwest Fisheries Science Center (SWFSC) were used to inform BIA boundaries for humpback whale feeding BIAs off the US West Coast. For each of the three datasets, two threshold values were chosen: one for creating parent BIAs (i.e., broader distribution) and one for creating child BIAs to represent core areas of use (core BIA, hereafter). Spatial filters were applied to restrict each dataset to the subset of area which met the density or habitat use thresholds. For each of the three data layers (tag HRs, HD model, sightings KDE), there is variability in values across species (or populations): (1) variability in density values across species (or populations) that relates to factors such as the geographic range of the species, behavior of the species, relative abundance, and survey coverage (or sample size of whales tagged); and (2) variability in the spatial sampling across the three data layers, due to the nature of the "survey" methods underlying each layer (i.e., large-scale ship-based line-transect surveys, free movements of tagged whales, localized small-boat surveys). Because of (1), setting exact, quantitative density values for each of the three layers for all species (e.g., 0.005 whales/km2 predicted density for all) would not result in species-specific biologically important areas. While equal quantile-based thresholds could be established across layers to mitigate this (e.g., 0.60 quantile for all data layers), this approach would fail to recognize substantial differences in the spatial scale that each layer reflects (i.e., variation from (2)). Therefore, in attempt to recognize biases that could arise from both (1) and (2) while also maintaining consistency across large whale F-BIAs, we applied a general approach in which threshold values for parent and child BIAs were defined by quantiles specific to each data layer but held the same across species. Layer-specific quantile-based threshold values were justified through expert elicitation (see manuscript for full explanation. The parent BIA HD model layer threshold was specified as the 0.80 quantile, and the core BIA threshold was one quantile higher than the parent BIA threshold (0.90 quantile) for all species. The parent BIA tagged whale home range (HR) threshold was specified as the 0.20 quantile of the total proportion of overlapping HRs and the core BIA threshold value was the 0.30 quantile of the total range of overlapping HRs. Quantiles of the proportion of overlapping HRs were the same across species. For the parent BIAs, the 90% sightings KDE contour was used and for the core BIAs, one intensity level higher (80% sightings KDE contour) was used.

All analyses were conducted within the program R (R Core Team, 2021). The inner (shoreward) boundary of the parent BIA was defined as the 30 m depth contour and the child (core) BIA was defined as the 70 m depth contour, based on the depth frequency of small boat sightings (see supplementary materials for figures). Our intention with these inner boundary definitions was to capture the nearshore nature of this species while recognizing that to some degree their densities decrease with increased distance to shore.

Each of the three data layers relies on different datasets that have their own strengths and weaknesses. The sighting database is based on more than 4,000 observations of humpback whales feeding or milling but is biased by the uneven distribution of effort. The tagging data is limited to 41 animals but provides detailed patterns of movement over extensive periods. The habitat-density model is based on ship-based line-transect surveys covering the entire West Coast including offshore waters but the surveys were conducted only every few years. Combining these data sets to find concurrence in the prediction of high-use regions helps address the individual data set biases and capitalize on their strengths, resulting the most robust way to define BIAs.

Habitat-based density model supporting information:
Multi-year averaged HD model predictions based on data collected from surveys from 1991 to 2018 were used in the BIA boundary determinations; details on survey design and HD modeling methods are described in Becker et al. (2020a, 2020b). The more recent predictions reported in Becker et al. (2020b) do not extend to the Washington US/Canada border, which has recently become an important feeding ground for humpback whales in the eastern North Pacific. However, earlier HD predictions reported by Becker et al. (2020a) do extend to this northern region, albeit based on lower survey effort (1991-2014), and therefore, the northern portion of predictions from Becker et al. (2020a) were extracted and merged with the Becker et al. (2020b) predictions to create a more complete HD model layer for humpback whales along the U.S. west coast. The parent BIA threshold was 0.0026 whales/km2 and the core BIA threshold was 0.0013 whales/km2.

Data sources: Oregon State University (accessed 2021); Cascadia Research Collective (accessed 2021); Southwest Fisheries Science Center, National Marine Fisheries Service (accessed 2021).

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 2

References: Baker, C. S., Steel, D., Calambokidis, J., Barlow, J., Burdin, A.M., and Clapham, P.J., et al. (2008). geneSPLASH: An initial, ocean-wide survey of mitochondrial (mt) DNA diversity and population structure among humpback whales in the North Pacific (Final report for Contract 2006-0093-008, National Fish and Wildlife Foundation).
Baker, C. S., Steel, D., Calambokidis, J., Falcone, E., Gonzalez-Peral, U., and Barlow, J., et al. (2013). Strong maternal fidelity and natal philopatry shape genetic structure in North Pacific humpback whales. Mar. Ecol. Prog. Ser. 494, 291-306. Doi:10.3354/meps10508

Becker, Elizabeth A., Karin A. Forney, Bruce J. Thayre, Amanda Debich, Gregory S. Campbell, Katherine Whitaker, Annie B. Douglas, Anita Gilles, Ryan Hoopes, and John A. Hildebrand. “Habitat-Based Density Models for Three Cetacean Species off Southern California Illustrate Pronounced Seasonal Differences.” Frontiers in Marine Science 4, no. 121 (2017): 1–14. https://doi.org/10.3389/fmars.2017.00121.

Becker, E.A., J.V. Caretta, K.A. Forney, J. Barlow, S. Brodie, R. Hoopes, J.G. Jacox, S.M. Maxwell, J.V. Redfern, N.B. Sisson, H. Welch, and E.L. Hazen. 2020a. Performance evaluation of cetacean species distribution models developed using generalized additive models and boosted regression trees. Ecology and Evolution 10:5759-5784 doi:10.1001/ece3.6316

Becker, E.A., K.A. Forney, D.L. Miller, P.C. Fidler, J. Barlow, and J.E. Moore. 2020b. Habitat-based density estimates for cetaceans in the California Current Ecosystem based on 1991-2018 survey data. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-638.

Calambokidis J, Barlow J (2004) Abundance of blue and humpback whales in the eastern North Pacific estimated by capture-recapture and line-transect methods. Marine Mammal Science 20(1):63-85.

Calambokidis, J., Falcone, E.A., Quinn, T.J., Burdin, A.M., Clapham, P.J., Ford, J.K.B., et al. (2008). SPLASH: Structure of Populations, Levels of Abundance and Status of Humpback Whales in the North Pacific (Final report for Contract AB133F-03-RP-00078 prepared by Cascadia Research for U.S. Department of Commerce, Seattle, Washington, USA). Available at http://www.cascadiaresearch.org/SPLASH/SPLASH-contract-Report-May08.pdf

Calambokidis J, Barlow J (2013) Updated abundance estimates of blue and humpback whales off the US West Coast incorporating photo-identifications from 2010 and 2011. Final Report for contract AB-133F-10-RP-0106. PSRG-2013-13R. 8pp.

Calambokidis, J., and J. Barlow. 2020. Abundance estimates for blue and humpback whales along the U.S. West Coast using data through 2018. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-634.

Calambokidis J, Falcone EA, Quinn TJ, Burdin AM, Clapham PJ, Ford JKB et al. (2008) SPLASH: Structure of Populations, Levels of Abundance and Status of Humpback Whales in the North Pacific. Final report for Contract AB133F-03-RP-00078 prepared by Cascadia Research for U.S. Department of Commerce, Seattle, Washington, USA. http://www.cascadiaresearch.org/SPLASH/SPLASH-contract-Report-May08.pdf

Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Martien, K.K., Hancock-Hanser, B.L., Lauf, M., Taylor, B.L., Archer, F.I., Urbán, J., Steel, D., Baker, C.S. and Calambokidis, J., 2020. Progress Report On Genetic Assignment Of Humpback Whales From The California-Oregon Feeding Aggregation To The Mainland Mexico And Central America Wintering Grounds.

Palacios, D.M., B.R. Mate, C.S. Baker, B.A. Lagerquist, L.M. Irvine, T.M. Follett, C.E. Hayslip, and D. Steel. 2020. Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean: Final Report for the Pacific Northwest Feeding Area in Summer/Fall 2019, Including Historical Data from Previous Tagging Efforts off the US West Coast. Prepared for Commander, U.S. Pacific Fleet. Submitted to Naval Facilities Engineering Command Southwest, under Cooperative Ecosystem Studies Unit, Department of the Navy Cooperative Agreement No. N62473-19-2-0002. Oregon State University, Newport, Oregon, 13 November 2020. 153 pp.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria https://www.R-project.org/

Schorr, G., E. Falcone, and C. Calambokidis. 2013. Summary of tag deployments on cetaceans off Washington, May 2010 to May 2013. Prepared for Commander, U.S. Pacific Fleet, Pearl Harbor, Hawaii. Submitted to Naval Facilities Engineering Command Pacific (NAVFAC PAC), Pearl Harbor, Hawaii 96860-3134, and Naval Facilities Engineering Command Northwest (NAVFAC NW), Silverdale, WA 98315-1101, under Contract # N62470-10-D-3011, issued to HDR Inc., San Diego, California 92123. 12 June 2013.

Supplementary Description 7. 16. Humpback whale feeding area

Species name: Humpback whale (*Megaptera novaeangliae*)

Descriptive name: Humpback whale West Coast - Core

BIA type: Feeding Area

BIA label: F-BIA3-s-b3-WC030-a

Transboundary across: None

Hierarchy: Hierarchical BIA; Child a

Importance score: 3 (Intensity: 3, Data support: 3)

Supporting notes for intensity score: We assigned an Intensity score of 3 to this BIA due to the following reasons:

• Humpback whales make extensive movements between low- latitude breeding grounds off Mexico and Central America to productive, high- latitude feeding grounds off the US West Coast, as characterized by this revised BIA.

• California/Oregon feeding humpback whales were recently estimated at 4,973 (SE=239) individuals (Calambokidis and Barlow, 2020) with a positive population growth trend over recent decades. Abundance of feeding humpback whales off Washington/southern British Columbia has also increased rapidly and are is estimated at 1,593 (SE=108) individuals (Calambokidis and Barlow, 2020); this rapid growth rate highlights the emerging importance of this region as a feeding ground for humpback whales migrating from low- latitude regions. The entire North Pacific population of humpback whales was estimated at around 20,000 individuals (Barlow et al. 2011, Wade 2017, Calambokidis et al. 2008), indicating the BIA described here represents a significant feeding area for humpback whales in the North Pacific.

• Humpback whales can be found off the US West Coast throughout the year although concentrations begin to increase in spring, peak in the summer and fall, and decrease in the late fall into winter. This seasonal occurrence aligns with seasonal prey availability along the US West Coast and the feeding BIA described here captures the spring to late fall period (March through November).

• HD model predicted density threshold value chosen for the BIA boundary determination process includes highest whale densities predicted for the study area.

• Although other feeding BIAs are being delineated for humpback whales in the North Pacific (e.g., Gulf of Alaska), individual humpbacks feeding off the US West Coast exhibit high site fidelity to particular feeding areas within the broader West Coast region and are unlikely to use other feeding BIAs delineated in the North Pacific .

Supporting notes for data support score: We assigned a Data Support score of 3 for this BIA due to the following lines of supporting evidence:

• This revised feeding BIA boundaries and corresponding time period were informed by additional sightings collected since the 2015 effort, spanning 34 years in total (1986-2020), and restricted to those where feeding or milling behaviors were observed.

• The addition of home ranges derived from 41 satellite tagged humpback whales from 2004-2019 provided a more unbiased (relative to dedicated survey efforts) perspective on the distribution of these whales feeding off the US West Coast. Satellite tag locations used to derive feeding home ranges were informed by movement model estimated behaviors (i.e., area-restricted search; Palacios et al., 2020).

• Although nearly half of the satellite tags included in this assessment were deployed off the Washington/Pacific Northwest coast, individuals tagged here generally remained within the Swiftsure Bank/Strait of Juan de Fuca regions ranging from 30 to 121 days in total, further supporting site fidelity to regional-specific feeding grounds and increasing importance of Washington/southern British Columbia as a feeding ground for humpback whales; these grounds are highlighted by the child (core) BIA.

• High- resolution, short-term tracks of tagged humpback whales feeding off of Washington reported by Schorr et al., (2013) further support the importance of the Washington/southernS British Columbia feeding grounds.

• Habitat-based density models used represent multi-year averages (spanning 1991-2018) of predictions during the summer/fall feeding season reflecting a broader distribution for the BIAs, and account for documented increases in humpback whale numbers in the study area over the study period (Becker et al., 2020b). Predicted densities agree with concentrations of both sightings of feeding/milling humpback whales and overlap of individual feeding humpback whale home ranges derived from satellite tag data.

• Abundance estimates specific to this region are contemporary and based on long-term sighting and photographic data (Calambokidis and Barlow, 2020).

• Child (core) BIA highlights feeding "hotspots" within the broader parent BIA boundary agreed among higher levels of each supporting data layer (concentrations of sightings, increased home range overlap from satellite tagged whales, higher habitat-based density model predictions).

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: Spatiotemporal variability indicator for both parent and core humpback whale F-BIAs is static. Large whales (such as humpbacks) may respond to spatiotemporal variation in the environment and some of the habitat models for large whales have incorporated dynamic variables to try and predict this (Forney et al. 2012, Becker et al 2020a. 2020b, Abrahms et al. 2019a, 2019b). More specifically, common variation in oceanographic conditions along the West Coast region often results in variation in the spatial distribution of large whale prey patches (e.g., krill, anchovies). As such, these whales may adjust their feeding behavior in space and time accordingly. However, we assigned a Spatiotemporal Variability Indicator score of "static" for all BIAs here, due to the following reasons: (1) for BIAs derived from the integrated approach (such as this one), we intentionally attempted to account for year-to-year variability in whale distribution by using multi-year averaged HD model outputs; (2) many of the BIAs' spatial extents cover large areas, such that whale distribution within those areas may change in response to the environment, but the spatial polygons themselves are unlikely to move in space or time.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the boundary certainty for both the parent and child humpback whale feeding BIAs described in this assessment, although see narrative on spatiotemporal variability above. This boundary is supported by three independent data sources (sightings from small-boat surveys, home ranges from long-term satellite tag deployments, multi-year averaged habitat-based density models) and combined have complementary strengths and weaknesses. The parent BIA boundary characterized here encompasses (1) nearly all visual sightings of feeding or milling humpback whales documented from 1986 through 2020; (2) the majority of shared home ranges from satellite tagged humpback whales; and (3) broad levels of predicted densities from HD models along the coastline. The resulting parent BIA corresponds well with the bathymetric features typically used by humpback whales feeding on prey aggregations during the March-November feeding season . The resulting child BIA reflects higher intensity values of all three supporting data layers, highlighting both known (e.g., Monterey Bay, Gulf of Farallones) and recently emerging (e.g., Swiftsure Bank) important primary feeding grounds for humpback whales within the broader coast-wide West Coast feeding ground.

Months of year designation is applicable: March, April, May, June, July, August, September, October, November

Tagging data supporting designation (Y/N): Y

# of tags: 41

# of years in which supporting tagging data collected: 5 (2004-2019)

Supporting information: Home ranges (HR) were estimated for forty-one humpback whales satellite-tagged by OSU along the west coast from 2004 through 2019. HRs were estimated for individual tagged whales using kernel density estimation methods as described in Palacios et al. (2020); details on satellite tag data processing methods are provided as supplementary material. We quantified intensity of space use by mapping each individual's home range on a 10 km x 10 km raster (all on the same grid), summing the total number of home ranges in each cell across all individuals, and calculating the proportion of the total 41 home ranges within each grid cell. For the parent BIA, we chose a proportion of all home ranges based on a threshold value of 0.025 (i.e., grid cells with greater than 0.025 proportion of all home ranges included). For the child BIA, a threshold value of 0.075 proportion of the total 41 home ranges was chosen.

Visual observations/records supporting designation (Y/N): Y

# of observations/records: 4777

# of years in which supporting visual data collected: 34 (1986-2020)

Supporting information: Sightings data used for the BIA boundary determinations were collected from dedicated small boat survey efforts conducted by CRC from 1986 through 2020; only sightings where feeding or milling behaviors were observed were included in this assessment (n=4,777). To create a layer based on this dataset, we used kernel density estimation (KDE) to generate a two-dimensional probability distribution using the package ks (Duong, 2021). The bandwidth value (smoothing parameter) was set to 10 kilometers . For the parent BIA, a broad KDE contour threshold of at least 90% was chosen. For the child BIA, a narrower KDE contour threshold of 80% was chosen.

Acoustic detections/records supporting designation (Y/N): N

Photo-ID evidence supporting designation (Y/N): Y

Supporting information: Calambokidis et al., 2008

Genetic analyses conducted supporting designation (Y/N): Y

Nature of supporting information: Strong

Supporting information: Baker et al. 2008, 2013

What factors justify the boundary selection?: A combination of sightings data collected from dedicated small boat survey efforts by Cascadia Research Collective (CRC), satellite tag data from long-term implant tags deployed by Oregon State University (OSU), and multi-year averaged habitat-based density (HD) models generated by Southwest Fisheries Science Center (SWFSC) were used to inform BIA boundaries for humpback whale feeding BIAs off the US West Coast. For each of the three datasets, two threshold values were chosen: one for creating parent BIAs (i.e., broader distribution) and one for creating child BIAs to represent core areas of use (core BIA, hereafter). Spatial filters were applied to restrict each dataset to the subset of area which met the density or habitat use thresholds. For each of the three data layers (tag HRs, HD model, sightings KDE), there is variability in values across species (or populations): (1) variability in density values across species (or populations) that relates to factors such as the geographic range of the species, behavior of the species, relative abundance, and survey coverage (or sample size of whales tagged); and (2) variability in the spatial sampling across the three data layers, due to the nature of the "survey" methods underlying each layer (i.e., large-scale ship-based line-transect surveys, free movements of tagged whales, localized small-boat surveys). Because of (1), setting exact, quantitative density values for each of the three layers for all species (e.g., 0.005 whales/km2 predicted density for all) would not result in species-specific biologically important areas. While equal quantile-based thresholds could be established across layers to mitigate this (e.g., 0.60 quantile for all data layers), this approach would fail to recognize substantial differences in the spatial scale that each layer reflects (i.e., variation from (2)). Therefore, in attempt to recognize biases that could arise from both (1) and (2) while also maintaining consistency across large whale F-BIAs, we applied a general approach in which threshold values for parent and child BIAs were defined by quantiles specific to each data layer but held the same across species. Layer-specific quantile-based threshold values were justified through expert elicitation (see manuscript for full explanation. The parent BIA HD model layer threshold was specified as the 0.80 quantile, and the core BIA threshold was one quantile higher than the parent BIA threshold (0.90 quantile) for all species. The parent BIA tagged whale home range (HR) threshold was specified as the 0.20 quantile of the total proportion of overlapping HRs and the core BIA threshold value was the 0.30 quantile of the total range of overlapping HRs. Quantiles of the proportion of overlapping HRs were the same across species. For the parent BIAs, the 90% sightings KDE contour was used and for the core BIAs, one intensity level higher (80% sightings KDE contour) was used.

All analyses were conducted within the program R (R Core Team, 2021). The inner (shoreward) boundary of the parent BIA was defined as the 30 m depth contour and the child (core) BIA was defined as the 70 m depth contour, based on the depth frequency of small boat sightings (see supplementary materials for figures). Our intention with these inner boundary definitions was to capture the nearshore nature of this species while recognizing that to some degree their densities decrease with increased distance to shore.

Each of the three data layers relies on different datasets that have their own strengths and weaknesses. The sighting database is based on more than 4,000 observations of humpback whales feeding or milling but is biased by the uneven distribution of effort. The tagging data is limited to 41 animals but provides detailed patterns of movement over extensive periods. The habitat-density model is based on ship-based line-transect surveys covering the entire West Coast including offshore waters but the surveys were conducted only every few years. Combining these data sets to find concurrence in the prediction of high-use regions helps address the individual data set biases and capitalize on their strengths, resulting the most robust way to define BIAs.

Habitat-based density model supporting information:
Multi-year averaged HD model predictions based on data collected from surveys from 1991 to 2018 were used in the BIA boundary determinations; details on survey design and HD modeling methods are described in Becker et al. (2020a, 2020b). The more recent predictions reported in Becker et al. (2020b) do not extend to the Washington US/Canada border, which has recently become an important feeding ground for humpback whales in the eastern North Pacific. However, earlier HD predictions reported by Becker et al. (2020a) do extend to this northern region, albeit based on lower survey effort (1991-2014), and therefore, the northern portion of predictions from Becker et al. (2020a) were extracted and merged with the Becker et al. (2020b) predictions to create a more complete HD model layer for humpback whales along the U.S. west coast. The parent BIA threshold was 0.0026 whales/km2 and the core BIA threshold was 0.0013 whales/km2.

Data sources: Oregon State University (accessed 2021); Cascadia Research Collective (accessed 2021); Southwest Fisheries Science Center, National Marine Fisheries Service (accessed 2021).

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 2

References: Baker, C. S., Steel, D., Calambokidis, J., Barlow, J., Burdin, A.M., and Clapham, P.J., et al. (2008). geneSPLASH: An initial, ocean-wide survey of mitochondrial (mt) DNA diversity and population structure among humpback whales in the North Pacific (Final report for Contract 2006-0093-008, National Fish and Wildlife Foundation).
Baker, C. S., Steel, D., Calambokidis, J., Falcone, E., Gonzalez-Peral, U., and Barlow, J., et al. (2013). Strong maternal fidelity and natal philopatry shape genetic structure in North Pacific humpback whales. Mar. Ecol. Prog. Ser. 494, 291-306. Doi:10.3354/meps10508

Becker, Elizabeth A., Karin A. Forney, Bruce J. Thayre, Amanda Debich, Gregory S. Campbell, Katherine Whitaker, Annie B. Douglas, Anita Gilles, Ryan Hoopes, and John A. Hildebrand. "Habitat-Based Density Models for Three Cetacean Species off Southern California Illustrate Pronounced Seasonal Differences." Frontiers in Marine Science 4, no. 121 (2017): 1–14. https://doi.org/10.3389/fmars.2017.00121.

Becker, E.A., J.V. Caretta, K.A. Forney, J. Barlow, S. Brodie, R. Hoopes, J.G. Jacox, S.M. Maxwell, J.V. Redfern, N.B. Sisson, H. Welch, and E.L. Hazen. 2020a. Performance evaluation of cetacean species distribution models developed using generalized additive models and boosted regression trees. Ecology and Evolution 10:5759-5784 doi:10.1001/ece3.6316

Becker, E.A., K.A. Forney, D.L. Miller, P.C. Fidler, J. Barlow, and J.E. Moore. 2020b. Habitat-based density estimates for cetaceans in the California Current Ecosystem based on 1991-2018 survey data. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-638.

Calambokidis J, Barlow J (2004) Abundance of blue and humpback whales in the eastern North Pacific estimated by capture-recapture and line-transect methods. Marine Mammal Science 20(1):63-85.

Calambokidis, J., Falcone, E.A., Quinn, T.J., Burdin, A.M., Clapham, P.J., Ford, J.K.B., et al. (2008). SPLASH: Structure of Populations, Levels of Abundance and Status of Humpback Whales in the North Pacific (Final report for Contract AB133F-03-RP-00078 prepared by Cascadia Research for U.S. Department of Commerce, Seattle, Washington, USA). Available at http://www.cascadiaresearch.org/SPLASH/SPLASH-contract-Report-May08.pdf

Calambokidis J, Barlow J (2013) Updated abundance estimates of blue and humpback whales off the US West Coast incorporating photo-identifications from 2010 and 2011. Final Report for contract AB-133F-10-RP-0106. PSRG-2013-13R. 8pp.

Calambokidis, J., and J. Barlow. 2020. Abundance estimates for blue and humpback whales along the U.S. West Coast using data through 2018. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-634.

Calambokidis J, Falcone EA, Quinn TJ, Burdin AM, Clapham PJ, Ford JKB et al. (2008) SPLASH: Structure of Populations, Levels of Abundance and Status of Humpback Whales in the North Pacific. Final report for Contract AB133F-03-RP-00078 prepared by Cascadia Research for U.S. Department of Commerce, Seattle, Washington, USA. http://www.cascadiaresearch.org/SPLASH/SPLASH-contract-Report-May08.pdf

Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Martien, K.K., Hancock-Hanser, B.L., Lauf, M., Taylor, B.L., Archer, F.I., Urbán, J., Steel, D., Baker, C.S. and Calambokidis, J., 2020. Progress Report On Genetic Assignment Of Humpback Whales From The California-Oregon Feeding Aggregation To The Mainland Mexico And Central America Wintering Grounds.

Palacios, D.M., B.R. Mate, C.S. Baker, B.A. Lagerquist, L.M. Irvine, T.M. Follett, C.E. Hayslip, and D. Steel. 2020. Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean: Final Report for the Pacific Northwest Feeding Area in Summer/Fall 2019, Including Historical Data from Previous Tagging Efforts off the US West Coast. Prepared for Commander, U.S. Pacific Fleet. Submitted to Naval Facilities Engineering Command Southwest, under Cooperative Ecosystem Studies Unit, Department of the Navy Cooperative Agreement No. N62473-19-2-0002. Oregon State University, Newport, Oregon, 13 November 2020. 153 pp.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria https://www.R-project.org/

Schorr, G., E. Falcone, and C. Calambokidis. 2013. Summary of tag deployments on cetaceans off Washington, May 2010 to May 2013. Prepared for Commander, U.S. Pacific Fleet, Pearl Harbor, Hawaii. Submitted to Naval Facilities Engineering Command Pacific (NAVFAC PAC), Pearl Harbor, Hawaii 96860-3134, and Naval Facilities Engineering Command Northwest (NAVFAC NW), Silverdale, WA 98315-1101, under Contract # N62470-10-D-3011, issued to HDR Inc., San Diego, California 92123. 12 June 2013.

Supplementary Description 7. 17. Killer whale small and resident pop.

Species name: Killer whale (*Orcinus orca*)

Stock or population: Southern Resident

Descriptive name: Southern Resident Killer Whale - Parent

BIA type: Small and Resident Pop.

BIA label: S-BIA2-s-b3-WC031-0a

Transboundary across: None

Hierarchy: Hierarchical BIA; Parent of children a

Importance score: 2 (Intensity: 2, Data support: 3)

Intensity matrix: Abundance: 3, Range: 1

Supporting notes for intensity score: Intensity score = 2

• Only 73 SRKWs as of July 2022 (abundance score = 3), divided amongst three separate pods (CWR, 2022).
• Parent BIA range is relatively large although used by three pods and overall abundance is small
• Parent BIA encompasses known range of this population along the US West Coast based on several data sources (sightings, satellite tag data, acoustic detections).
• No other S-BIA (or any other type of BIA) is being delineated for SRKWs

The resulting range size of the parent BIA is 60,348 km2 (range size score = 1).

Supporting notes for data support score: Data support score = 3

• Long-term photo-identification catalog and continuous monitoring efforts (when SRKWs sighted) support the abundance value of 73 individuals (CWR, 2022)
• The parent BIA and a portion of the child (core) BIA (around San Juan Islands) were based on published critical habitat boundaries, which incorporate habitat features known to be important to their survival.
• Important areas in the Salish Sea (inland waters) are primarily supported by over 30 years of sighting data (Hauser et al., 2007; Olson et al., 2018). Although the majority of these data capture only a portion of their range (Salish Sea), limited SRKW sightings along the outer coast where there is extensive community scientist effort (e.g., whale watching operations in Monterey Bay) may reflect that it is very unlikely that the SRKWs spend a lot of time in areas farther south within the West Coast region.
• Sightings in typical high-use areas have declined over recent years (Ettinger et al., 2022; Hanson et al. 2021; Shields et al. 2018), adding uncertainty to a contemporary understanding of their spatial use
• Important areas along the outer US west coast are supported by movements from eight satellite tagged SRKWs, from all three pods (3-95 days of data), which complement our understanding of their use outside of the Salish Sea and provide a less biased (compared to dedicated survey effort) depiction of their habitat use in areas that are often inaccessible for surveys due to poor working conditions. The importance of this area has been more recently supported through passive acoustic studies (Emmons et al., 2021)
• Kernel density methods used to derive core areas from satellite tag data are widely used and robust, and accounted for varying deployment durations
• Portion of the child BIA along the outer coast includes the mouths of river systems that play a large role in supporting prey for SRKWs (e.g., Columbia River; Hanson et al., 2021)
• SRKW's known range does extend further north along British Columbia to southern Alaska but those regions are not part of this region's BIA assessment
• BIA boundaries include important transboundary areas as defined by the Department of Fisheries and Oceans Canada (DFO's) critical habitat

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: We assigned this score for this BIA as static. Although there are likely factors that may influence the spatiotemporal distribution of this population within their range, they are not thoroughly described to date.

Boundary certainty: 3

Supporting notes for boundary certainty: We have high confidence in the parent BIA boundary boundary for Southern Resident Killer whales in the US West Coast region. The parent BIA boundary is based on published critical habitat for this population, which was informed by this population's known extent in US and transboundary waters identified through sightings, satellite tag data, and acoustic detections.

Months of year designation is applicable: Year-round

Tagging data supporting designation (Y/N): Y

# of tags: 8

# of years in which supporting tagging data collected: 5 (2012-2016)

Supporting information: The parent BIA is based on designated critical habitat, which is informed by several types of information including movements from satellite tagged whales (e.g., off the West Coast).

Visual observations/records supporting designation (Y/N): Y

Supporting information: The parent BIA is based on designated critical habitat, which is informed by several types of information including visual observations from dedicated and opportunistic efforts (e.g., off the West Coast).(NMFS, 2021; Fisheries and Oceans Canada, 2011)

Acoustic detections/records supporting designation (Y/N): Y

Supporting information: Hanson et al. 2013, 2018; Emmons et al. 2021

Photo-ID evidence supporting designation (Y/N): Y

# of individuals photographed: 73 individuals

# of years of photo records to compare: 1976-2022

Supporting information: Center for Whale Research, 2022

Genetic analyses conducted supporting designation (Y/N): Y

Nature of supporting information: Strong

Supporting information: Hoelzel et al., 1998

What factors justify the boundary selection?: Here we delineated an S-BIA for the SRKW population for the US West Coast region, which was not previously designated in Calambokidis et al. (2015). While there have been some records of SRKW occurrence in waters as north as southeast Alaska, for this assessment we focused on the extent of their known range within the West Coast region and incorporated known biologically important areas in adjacent Canadian waters of the Salish Sea. For the parent BIA, we primarily used existing spatial boundaries that have been well-justified through current understanding of their distribution: the US NMFS critical habitat boundary and the Fisheries and Oceans Canada (DFO) critical habitat boundary. Additionally, we included known portions of SRKW range that were excluded from the critical habitat designations. We further identified core areas of use (child BIA) using information on their movements obtained from satellite tracking data and a core area in the Salish Sea previously identified as critical habitat.

The basis for the parent BIA for SRKWs was a combination of the critical habitat boundaries defined by NOAA Fisheries (US waters) and DFO Canada (NMFS, 2021; Fisheries and Oceans Canada, 2011). Both critical habitat boundaries reflect areas within the geographical range of SRKWs that contained physical and/or biological features important to their survival. In August 2021, NOAA Fisheries revised the critical habitat for this population by extending the boundary from the Strait of Juan de Fuca to outer coast waters (between 6 and 200m isobaths) with Point Sur, California representing the southernmost extent (NMFS, 2021). While critical habitat excluded The Quinault Military Range Site off the Washington coast, since BIAs are based solely on biological criteria, we include the portion of the range that was deemed biologically important for SRKWs. The parent BIA was drawn by combining critical habitat boundaries from both NOAA Fisheries and DFO. In addition, the portion of the NOAA Fisheries critical habitat boundary within the inner Salish Sea (around San Juan Islands) was extended across the Canadian border and just north the capture the mouth of the Fraser River.

Data sources: Fisheries and Oceans Canada (accessed 2021); National Marine Fisheries Service (accessed 2021)

Approximate % of population that uses this area for the designated purpose (if known): 100

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 1

References: Baird, R.W. 2001. Status of killer whales, Orcinus orca, in Canada. Canadian Field Naturalist 115(4):676-701

Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Ettinger, A.K., Harvey, C.J., Emmons, C., Hanson, M.B., Ward, E.J., Olson, J.K., et al. (2022). Shifting phenology of an endangered apex predator mirrors changes in its favored prey. Endanger. Species Res. 48, 211-223. Doi:10.3354/esr01192

Fisheries and Oceans Canada. 2011. Recovery strategy for the Northern and Southern Resident killer whales (Orcinus orca) in Canada. Species at Risk Act Recovery Strategy Series, Fisheries & Oceans Canada, Ottawa, ix + 80 pp. Retrieved from https://www.sararegistry.gc.ca/document/doc1341a/ind_e.cfm October 2021

Ford, J.K.B., G.M. Ellis, and K.C. Balcomb. 2000. Killer whales: The natural history and genealogy of Orcinus orca in British Columbia and Washington, UBC Press, Vancouver

Ford, J.K.B., G.M. Ellis, P.F. Olesiuk, and K.C. Balcomb. 2010. Linking killer whale survival and pre abundance: food limitation in the oceans' apex predator? Biology Letters 6(1):139-142

Hanson, M.B., C.K. Emmons, E.J. Ward, J.A. Nystuen, and M.O. Lammers. 2013. Assessing the coastal occurrence of endangered killer whales using autonomous passive acoustic recorders. Journal of Acoustical Society of America 134:3486-3495

Hanson, M.B., E.J. Ward, C.K. Emmons, and M.M. Holt. 2018. Modeling the occurrence of endangered killer whales near a U.S. Navy Training Range in Washington State using satellite-tag locations to improve acoustic detection data. Prepared for: U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI. Prepared by: National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center under MIPR N00070-17-MP-4C419. 8 January 2018. 33pp.

Hanson, M.B., C.K. Emmons, M.J. Ford, M. Everett, K. Parsons, L.K. Park, J. Hempelmann, D.M. Van Doornik, G.S. Schorr, J.K. Jacobsen, M.F. Sears, M.S. Sears, J.G. Sneva, R.W. Baird, and L. Barre. 2021. Endangered predators and endangered prey: Seasonal diet of Southern Resident killer whales. PLoS ONE 16(3):e0247031 doi:10.1371/journal.pone.0247031

Hauser, D.D.W., K.L. Laidre, R.S. Suydam, and P.R. Richard. 2014. Population-specific home ranges and migration timing of Pacific Arctic beluga whales (Delphinapterus leucas). Polar Biology 37:1171-1183

Hoelzel, A.R., Dahlheim, M., and Stern, S.J. 1998. Low genetic variation among killer whales (Orcinus orca) in the Eastern North Pacific and genetic differentiation between foraging specialists. Journal of Heredity, 89:121-128

Holt, M.M., J.B. Tennessen, M.B. Hanson, C.K. Emmons, D.A. Giles, J.T. Hogan, and M.J. Ford. 2021. Vessels and their sounds reduce prey capture effort by endangered killer whales (Orcinus orca). Marine Environmental Research 170:105429

Krahn, M.M., M.J. Ford, W.F. Perrin, P.R. Wade, R.P. Angliss, M.B. Hanson, B.L. Taylor, G.M. Ylitalo, M.E. Dahlheim, J.E. Stein, and R.S. Waples. 2004. 2004 Status review of Southern Resident killer whales (Orcinus orca) under the Endangered Species Act. U.S. Dept. Commerce, NOAA Technical Memorandum NMFS-NWFSC-62 73 p.

Krahn, M.M., M.B. Hanson, R.W. Baird, R.H. Boyer, D.G. Burrows, C.K. Emmons, J.K.B. Ford, L.L. Jones, D.P. Noren, P.S. Ross, G.S. Schorr, and T.K. Collier. 2009. Persistent organic pollutants and stable isotopes in biopsy samples (2004/2006) from Southern Resident killer whales. Marine Pollution Bulletin 54(12):1903-1911

NMFS. 2021. Revision of the Critical Habitat Designation for Southern Resident Killer Whales: Final biological report (to accompany the Final Rule). 112pp + Appendices. Retrieved from https://repository.library.noaa.gov/view/noaa/31587 October 2021

Olson, J.K., J. Wood, R.W. Osborne, L. Barrett-Lennard, and S. Larson. 2018. Sightings of southern resident killer whales in the Salish Sea 1976-2014: the importance of a long-term opportunistic dataset.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria https://www.R-project.org/

Shields, M.W., J. Lindell, and J. Woodruff. 2018. Declining spring usage of core habitat by endangered fish-eating killer whales reflects decreased availability of their primary prey. Pacific Conservatoin Biology doi:10.1071/PC17041

Wasser, S.K., J.I. Lundin, K. Ayres, E. Seely, D. Giles, K. Balcomb, J. Hempelmann, K. Parsons, and R. Booth. 2017. Population growth is limited by nutritional impacts on pregnancy success in endangered Southern Resident killer whales (Orcinus orca). PLoS ONE 12(6):e0179824

Supplementary Description 7. 18. Killer whale small and resident pop.

Species name: Killer whale (*Orcinus orca*)

Stock or population: Southern Resident

Descriptive name: Southern Resident Killer Whale - Core

BIA type: Small and Resident Pop.

BIA label: S-BIA3-s-b2-WC031-a

Transboundary across: None

Hierarchy: Hierarchical BIA; Child a

Importance score: 3 (Intensity: 3, Data support: 3)

Intensity matrix: Abundance: 3, Range: 3

Supporting notes for intensity score: The child BIA for Southern Resident killer whales described here represents intensified use relative to the broader parent BIA. As such, it is appropriate here to score the child BIA the highest intensity score (3).

• Only 73 SRKWs as of July 2022, divided amongst three separate pods (CWR, 2022).
• Area of this BIA is 14,809 km2
• Areas of concentrated use highlighted by child BIAs and are either based on or aligned with important areas identified from several different data sources (e.g., sightings (Hauser et al., 2007; Olson et al., 2018); satellite tag data (Hanson et al., 2018); acoustic detections, (Hanson et al., 2013, 2018; Emmons et al., 2021)).
• No other S-BIA (or any other type of BIA) is being delineated for SRKWs
• Approximate proportion of the population that is contained within child BIAs: 50%, although recognize that there is uncertainty in this estimate.

Supporting notes for data support score: • • Long-term photo-identification catalog and continuous monitoring efforts (when SRKWs sighted) support the abundance value of 75 individuals (CWR, 2022)
• The parent BIA and a portion of the child BIA (around San Juan Islands) were based on published critical habitat boundaries, which incorporate habitat features known to be important to their survival.
• Important areas in the Salish Sea (inland waters) are primarily supported by over 30 years of sighting data (Olson et al., 2018). Although the majority of these data capture only a portion of their range (Salish Sea), limited SRKW sightings along the outer coast where there is extensive community scientist effort (e.g., whale watching operations in Monterey Bay) may reflect that it is very unlikely that the SRKWs spend a lot of time in areas farther south within the West Coast region.
• Sightings in typical high-use areas have declined over recent years (Hanson et al. 2021; Shields et al. 2018), adding uncertainty to a contemporary understanding of their spatial use
• Important areas along the outer US west coast are supported by movements from eight satellite tagged SRKWs, from all three pods (3-95 days of data; Table 1), which complement our understanding of their use outside of the Salish Sea and provide a less biased (compared to dedicated survey effort) depiction of their habitat use in areas that are often inaccessible for surveys due to poor working conditions. The importance of this area has been more recently supported through passive acoustic studies (Emmons et al., 2021)
• Kernel density methods used to derive core areas from satellite tag data are widely used and robust, and accounted for varying deployment durations
• Portion of the child BIA along the outer coast includes the mouths of river systems that play a large role in supporting prey for SRKWs (e.g., Columbia River; Hanson et al., 2021)
• SRKW's known range does extend further north along British Columbia to southern Alaska but those regions are not part of this region's BIA assessment
• BIA boundaries include important transboundary areas as defined by the Department of Fisheries and Oceans Canada (DFO's) critical habitat

Spatiotemporal variability: s

Supporting notes for spatiotemporal variability: We assigned this score for this BIA as static. Although there are likely factors that may influence the spatiotemporal distribution of this population within their range, they are not thoroughly described to date.

Boundary certainty: 2

Supporting notes for boundary certainty: We have intermediate confidence in the child BIA boundary for Southern Resident Killer whales in the US West Coast region. The child BIA intends to represent the core range for this population and is based on both satellite tag data (less biased than sightings) and a core range around the San Juan Islands that is part of published critical habitat. However, sighting rates overall have declined over recent years and without additional information on movements from satellite tag data, we cannot confidently assign a contemporary and comprehensive description of their core range.

Months of year designation is applicable: Year-round

Tagging data supporting designation (Y/N): Y

# of tags: 5

# of years in which supporting tagging data collected: 5 (2012-2016)

Supporting information: Kernel density estimation (KDE) was used to generate a utility distribution (UD) of the sample population (Worton, 1989), and a 50% isopleth of the UD was used to represent the core range of SRKWs during the months covered by satellite tag deployments. Location data were available from 8 deployments on SRKWs from 2012 through 2016; tags were deployed during winter months (Table 1; Hanson et al., 2018). Detailed methods on satellite tag data processing methods will be provided as supplementary material and are the same used for the Hawaiʻi region by Kratofil et al. (this issue). Briefly, Kalman-smoothed Argos location data were first processed through the Douglas Argos Filter (Douglas et al., 2012) via Movebank (Kranstauber et al., 2011) to remove erroneous locations, and subsequently fit to a continuous-time correlated random walk model and predicted at a 4-hour timestep via crawl (Johnson et al., 2008; Johnson and London, 2018). Locations were re-routed around land (land polygon with 50m distance buffer) using the pathroutr package (London, 2020). Although locations were obtained more frequently than this 4-hour interval, kernel density analyses are sensitive to autocorrelation; as such, a 4-hour step was used to attempt to mitigate autocorrelation. Two tracks were excluded from kernel density analysis due to limited data that may inflate tagging locality bias (3 days of data), and an additional track was excluded as this individual behaved in concert with one other tagged SRKW throughout its deployment (the shorter of the two tracks was excluded to reduce pseudoreplication). The final analytical sample size was 5 tracks (3,944 filtered Argos locations). All tag locations were pooled together, and the contribution of each tag's location was weighted to the overall kernel density based on deployment length, and the KDE was re-scaled so it integrated to 1 (Hauser et al., 2014; Hill et al., 2019), such that locations from shorter deployments would have less weight than those with longer deployments. Kernel densities were estimated using the bivariate plug-in bandwidth (or smoothing parameter) matrix (Duong & Hazelton, 2003, 2005; Duong, 2007) accessed through the ks package for R (Duong, 2021). The location weighting was completed using the weights argument within the ks package (Duong, 2021).

Visual observations/records supporting designation (Y/N): Y

Supporting information: Part of the child BIA is based on designated critical habitat, which is informed by several types of information including visual observations from dedicated and opportunistic efforts (e.g., off the West Coast).(NMFS, 2021; Fisheries and Oceans Canada, 2011)

Acoustic detections/records supporting designation (Y/N): Y

Supporting information: Hanson et al., 2013, 2018; Emmons et al., 2021

Photo-ID evidence supporting designation (Y/N): Y

# of individuals photographed: 73 individuals

# of years of photo records to compare: 1976-2022

Supporting information: Center for Whale Research, 2022

Genetic analyses conducted supporting designation (Y/N): Y

Nature of supporting information: Strong

Supporting information: Hoelzel et al., 1998

What factors justify the boundary selection?: Here we delineated an S-BIA for the SRKW population for the US West Coast region, which was not previously designated in Calambokidis et al. (2015). While there have been some records of SRKW occurrence in waters as north as southeast Alaska, for this assessment we focused on the extent of their known range within the West Coast region and incorporated known biologically important areas in adjacent Canadian waters of the Salish Sea. For the parent BIA, we primarily used existing spatial boundaries that have been well-justified through current understanding of their distribution: the US NMFS critical habitat boundary and the Fisheries and Oceans Canada (DFO) critical habitat boundary. Additionally, we included known portions of SRKW range that were excluded from the critical habitat designations. We further identified core areas of use (child BIA) using information on their movements obtained from satellite tracking data and a core area in the Salish Sea previously identified as critical habitat.

A child BIA was delineated for SRKWs with the intent to highlight areas of intensified use (hereafter, core range) within their overall range. The basis of the core range was a combination of NOAA's critical habitat core area (extended over the CA border) and high-density areas identified through kernel density analyses of satellite tag data (details on satellite tag data methods are described below). While NOAA's critical habitat core range is designated as a "summer core range" (around San Juan Islands), SRKW occurrence in this region during summer months has declined considerably over recent years; the importance of this area for SRKWs may not be as strongly associated with this particular season as has been the case historically (Ettinger et al., 2022; Hanson et al. 2021; Shields et al. 2018). As such, we specify the core range described here to exist year-round for SRKWs.

Data sources: National Marine Fisheries Service (accessed 2021)

Approximate % of population that uses this area for the designated purpose (if known): 50

Approximate # of areas known specifically for this behavior (if feeding/cow-calf/mating/migratory) for this population: 1

References: Baird, R.W. 2001. Status of killer whales, Orcinus orca, in Canada. Canadian Field Naturalist 115(4):676-701
Calambokidis, J, GH Steiger, C Curtice, J Harrison, MC Ferguson, E Becker, M DeAngelis, and SM Van Parijs. 2015. Biologically Important Areas for Selected Cetaceans within U.S. Waters – West Coast Region. Aquatic Mammals 41(1), 39-53, DOI 10.1578/AM.41.1.2015.39

Douglas, D.C., R. Weinzierl, S.C. Davidson, R. Kays, M. Wikelski, and G. Bohrer. 2012. Moderating Argos location errors in animal tracking data. Methods in Ecology and Evolution 3(6):999-1007.

Duong, T., and M.L. Hazelton. 2003. Plug-in bandwidth matrices for bivariate kernel density estimation. Journal of Nonparametric Statistics 15:17-30.

Duong, T., and M.L. Hazelton. 2005. Cross-validation bandwidth matrices for multivariate kernel density estimation. Scandinavian Journal of Statistics 32:485-506.

Duong, T. 2007. Ks: Kernel density estimation and kernel discriminant analysis for multivariate data in R. Journal of Statistical Software 21:1-16.

Duong, T. 2021. Ks: Kernel Smooth. R package version 1.13.2. https://CRAN.R-project.org/package=ks

Ettinger, A.K., Harvey, C.J., Emmons, C., Hanson, M.B., Ward, E.J., Olson, J.K., et al. (2022). Shifting phenology of an endangered apex predator mirrors changes in its favored prey. Endanger. Species Res. 48, 211-223. Doi:10.3354/esr01192

Fisheries and Oceans Canada. 2011. Recovery strategy for the Northern and Southern Resident killer whales (Orcinus orca) in Canada. Species at Risk Act Recovery Strategy Series, Fisheries & Oceans Canada, Ottawa, ix + 80 pp. Retrieved from https://www.sararegistry.gc.ca/document/doc1341a/ind_e.cfm October 2021

Ford, J.K.B., G.M. Ellis, and K.C. Balcomb. 2000. Killer whales: The natural history and genealogy of Orcinus orca in British Columbia and Washington, UBC Press, Vancouver

Ford, J.K.B., G.M. Ellis, P.F. Olesiuk, and K.C. Balcomb. 2010. Linking killer whale survival and pre abundance: food limitation in the oceans' apex predator? Biology Letters 6(1):139-142

Hanson, M.B., C.K. Emmons, E.J. Ward, J.A. Nystuen, and M.O. Lammers. 2013. Assessing the coastal occurrence of endangered killer whales using autonomous passive acoustic recorders. Journal of Acoustical Society of America 134:3486-3495

Hanson, M.B., E.J. Ward, C.K. Emmons, and M.M. Holt. 2018. Modeling the occurrence of endangered killer whales near a U.S. Navy Training Range in Washington State using satellite-tag locations to improve acoustic detection data. Prepared for: U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI. Prepared by: National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center under MIPR N00070-17-MP-4C419. 8 January 2018. 33pp.

Hanson, M.B., C.K. Emmons, M.J. Ford, M. Everett, K. Parsons, L.K. Park, J. Hempelmann, D.M. Van Doornik, G.S. Schorr, J.K. Jacobsen, M.F. Sears, M.S. Sears, J.G. Sneva, R.W. Baird, and L. Barre. 2021. Endangered predators and endangered prey: Seasonal diet of Southern Resident killer whales. PLoS ONE 16(3):e0247031 doi:10.1371/journal.pone.0247031

Hauser, D.D.W., K.L. Laidre, R.S. Suydam, and P.R. Richard. 2014. Population-specific home ranges and migration timing of Pacific Arctic beluga whales (Delphinapterus leucas). Polar Biology 37:1171-1183

Hill, M.C., A.R. Bendlin, A.M. Van Cise, A. Milette-Winfree, A.D., Ligon, A.C. Ü, M.H. Deakos, and E.M. Oleson. 2019. Short-finned pilot whales (Globicephala macrorhynchus) of the Mariana Archipelago: individual affiliations, movements, and spatial use. Marine Mammal Science 35(3):797-824 doi:10.1111/mms.12567

Hoelzel, A.R., Dahlheim, M., and Stern, S.J. 1998. Low genetic variation among killer whales (Orcinus orca) in the Eastern North Pacific and genetic differentiation between foraging specialists. Journal of Heredity, 89:121-128

Holt, M.M., J.B. Tennessen, M.B. Hanson, C.K. Emmons, D.A. Giles, J.T. Hogan, and M.J. Ford. 2021. Vessels and their sounds reduce prey capture effort by endangered killer whales (Orcinus orca). Marine Environmental Research 170:105429

Johnson, D.S., J.M. London, M.-A. Lea, and J.W. Durban. 2008. Continuous-time correlated random walk model for animal telemetry data. Ecology 89:1208-1215 doi:10.1890/07-1032.1

Johnson, D.S., and J.M. London. 2018. Crawl: an R package for fitting continuous-time correlated random walk models to animal movement data. Zenodo https://doi.org/10.5281/zenodo.596464

Krahn, M.M., M.J. Ford, W.F. Perrin, P.R. Wade, R.P. Angliss, M.B. Hanson, B.L. Taylor, G.M. Ylitalo, M.E. Dahlheim, J.E. Stein, and R.S. Waples. 2004. 2004 Status review of Southern Resident killer whales (Orcinus orca) under the Endangered Species Act. U.S. Dept. Commerce, NOAA Technical Memorandum NMFS-NWFSC-62 73 p.

Krahn, M.M., M.B. Hanson, R.W. Baird, R.H. Boyer, D.G. Burrows, C.K. Emmons, J.K.B. Ford, L.L. Jones, D.P. Noren, P.S. Ross, G.S. Schorr, and T.K. Collier. 2009. Persistent organic pollutants and stable isotopes in biopsy samples (2004/2006) from Southern Resident killer whales. Marine Pollution Bulletin 54(12):1903-1911

Kranstauber, B., A. Cameron, R. Weinzerl, T. Fountain, S. Tilak, M. Wikelski, and R. Kays. 2011. The Movebank data model for animal tracking. Environmental Modeling & Software 26:834-835

London, J.M. 2020. Pathroutr: an R package for (re-)routing paths around barriers (version v0.1.1-beta). Zenodo http://doi.org/10.5281/zenodo.4321827

NMFS. 2021. Revision of the Critical Habitat Designation for Southern Resident Killer Whales: Final biological report (to accompany the Final Rule). 112pp + Appendices. Retrieved from https://repository.library.noaa.gov/view/noaa/31587 October 2021

Olson, J.K., J. Wood, R.W. Osborne, L. Barrett-Lennard, and S. Larson. 2018. Sightings of southern resident killer whales in the Salish Sea 1976-2014: the importance of a long-term opportunistic dataset.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria https://www.R-project.org/

Shields, M.W., J. Lindell, and J. Woodruff. 2018. Declining spring usage of core habitat by endangered fish-eating killer whales reflects decreased availability of their primary prey. Pacific Conservatoin Biology doi:10.1071/PC17041

Wasser, S.K., J.I. Lundin, K. Ayres, E. Seely, D. Giles, K. Balcomb, J. Hempelmann, K. Parsons, and R. Booth. 2017. Population growth is limited by nutritional impacts on pregnancy success in endangered Southern Resident killer whales (Orcinus orca). PLoS ONE 12(6):e0179824