MARINE MAMMALS – RISK ASSESSMENT

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SOUND BITE

Overall, it is clear that groundfish fishing fleets overlap with various cetaceans found in the CCLME, but it is unclear whether or not this overlap presents a substantial risk to the viability of these cetacean populations.

EXECUTIVE SUMMARY

- Many cetacean populations worldwide are confronted by a multitude of anthropogenic threats. Commercial whaling, ambient ocean noise, vessel collisions, gear entanglement, resource competition, habitat disturbance and global climate change are examples of some of these threats. There is substantial evidence in the literature that cetaceans are sensitive to many of the aforementioned threats imposed by commercial fishing activities. However, few studies have addressed the potential vulnerability of a given cetacean species to an entire fishing fleet operating over a large marine ecosystem. Further, there is a paucity of data on inter -specific and -fleet overlap of commercial fishing activities on cetaceans.
- In this report, we overlaid spatially explicit predicted mean annual density of 12 cetacean species within the CCLME with observer based West Coast Groundfish Fishery (WCGF) commercial fishing effort data for fixed-gear, at-sea hake midwater trawl, and bottom trawl fleets. We quantified the vulnerability of each species to each fleet type by multiplying the predicted mean annual cetacean density by the measured fishing fleet effort (in hours) from 2002-2009 (see Figure MMR-EX1 for example map for humpback whales).
- We found that there was enormous interspecific and interfleet variability in the overlap between cetaceans and fishing fleets (Figure MMR-EX2) and this variability was not consistent over time. While many of the species had relatively low overlap rates, others had significant exposure to some of the fishing fleets. While there is not a lot of evidence of direct mortality from these fleets, our results suggest there is substantial opportunity for sublethal affects on some cetacean species.
- Our analyses are an important first step in generating formal risk assessments for quantifying the population impacts of various fishing fleets on cetaceans living in the CCLME.

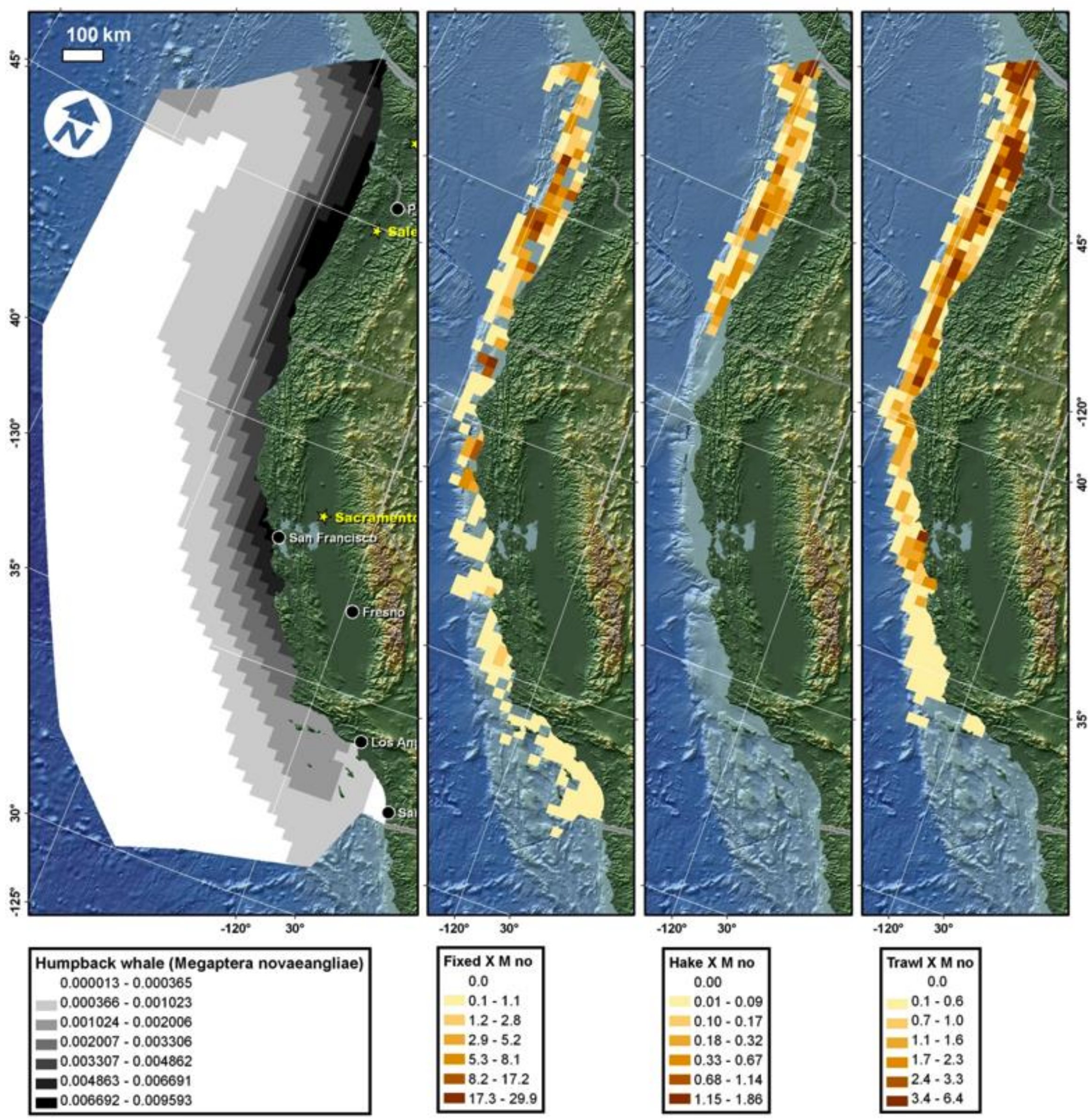

Figure MMR-EX1. Left map: modeled humpback whale mean density expressed as the number of individuals/yr/km2. Three narrow maps: overlap values for humpback whale with the fixed, hake and trawl fleets

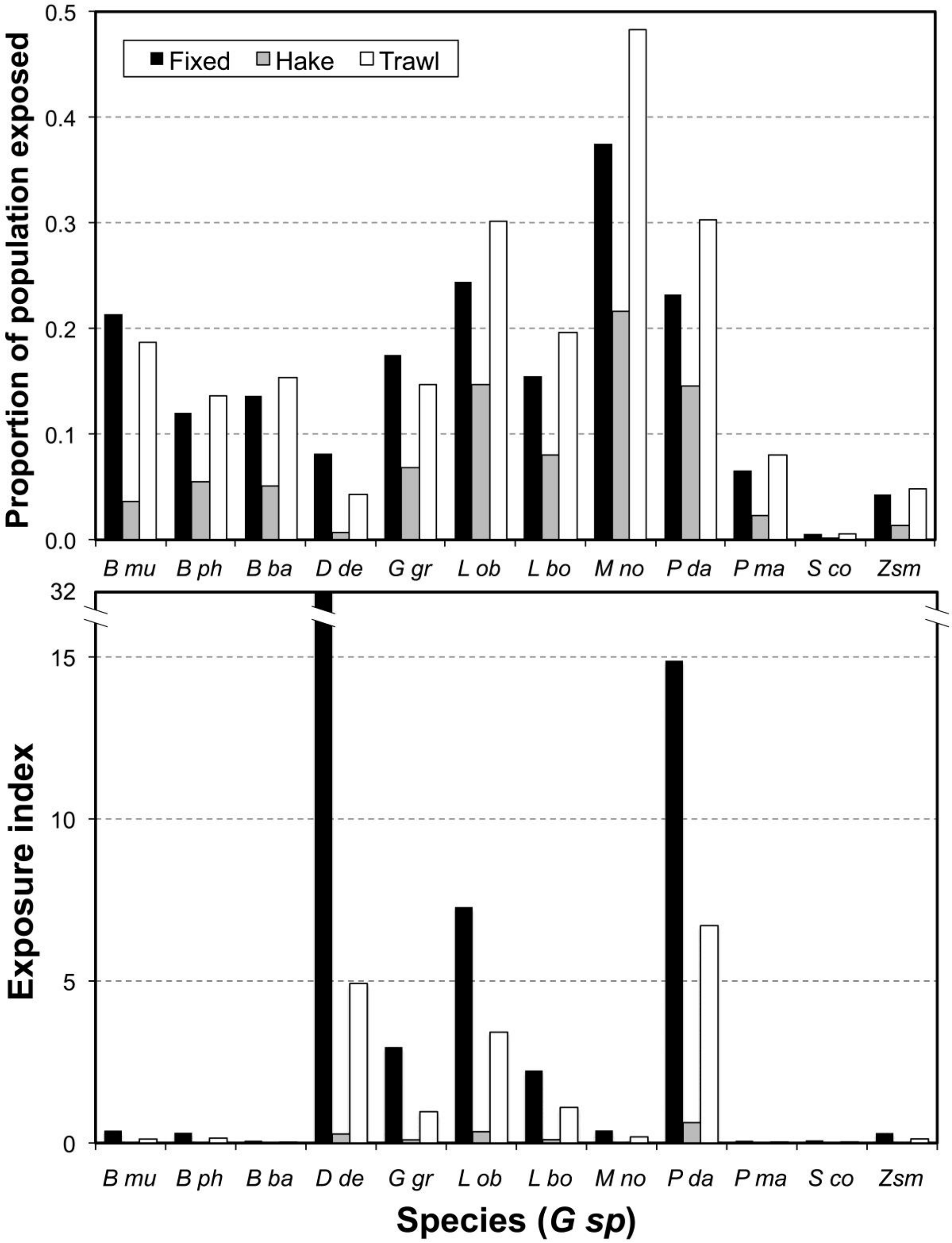

Figure MMR-EX2. Modeled proportion (upper) and cumulative exposure index (lower) of each cetacean species population that overlaped with each of the three commercial fishing fleets (from 2002-2009), for each of the 12 cetacean species. B ba = Baird's beaked whale; B mu = blue whale; B ph = fin whale; D de = short-beaked common dolphin; G gr = Risso's dolphin; L bo = northern right whale dolphin; L ob = Pacific white-sided dolphin; M no = humpback whale; P da = Dall's porpoise; P ma = sperm whale; S co = striped dolphin; and, Zsm = small beaked whales

DETAILED REPORT

DESCRIPTION OF ECOSYSTEM COMPONENT

This report describes a risk assessment that we ran on various cetacean species distributed in the CCLME. There are four cetacean species that are endangered and protected by the Endangered Species Act (ESA), and the other eight species are protected under the Marine Mammal Protection Act (MMPA, see Table MMR1).

The goal of this assessment was twofold. First, map and quantify the general patterns of overlap between the 12 species of cetaceans and three of the major groundfish fishing fleets operating in the CCLME. Second, map and quantify interspecific and interfleet differences in the overlap spatio-temporal patterns of overlap. From this we quantified the potential overlap (a proxy for vulnerability) for each cetacean species. The risk imposed by various groundfish fishing fleets is poorly understood in the CCLME. Given that cetaceans are a protected species and are likely key players in marine interaction webs (CIESM 2004, Paine 2006), it is important to include them in any IEA. The status of these cetacean stock ranges from unknown to endangered (Carretta et al. 2011), so it seems prudent to include these long-lived animals with low intrinsic population growth rates in this IEA.

Cetaceans around the world face a myriad stresses on their populations. Commercial whaling was once the primary threat to many cetaceans, but with the international ban on numerous whaling operations, and the Marine Mammal Protection Act (MMPA) many populations have rebounded. Nevertheless, commercial whaling activities continue in some areas and numerous lethal and sublethal anthropogenic threats to the viability of cetaceans persist. The list includes, but is not limited to, anthropogenic stress (Curry 1999, Fair and Becker 2000), vessel collisions (Panigada et al. 2006), noise (Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals 2003, Romano et al. 2004), exposure to toxins (hydrocarbons, exhaust, etc. (Jarman et al. 1996, Marsili et al. 2001)), entanglement with fishing gear (Read et al. 2006) and marine debris (Williams et al. 2011), resource competition and habitat disturbance from fishing (Dayton et al. 1995, DeMaster et al. 2001, Herr et al. 2009), and global climate change (MacLeod 2009).

There is substantial evidence in the literature documenting direct mortality of various cetaceans from interactions with commercial and recreational fishing gear (Read et al. 2006). For example, sperm whales (*Physeter macrocephalus*), are especially susceptible to deepwater gillnets and bottom-set longline gear (Di Natale and Notarbartolo di Sciara 1994, Haase and Felix 1994, Félix et al. 1997, Hill et al. 1999, Straley et al. 2005). They have been observed breaking through or carrying away fishing gear and may die or are seriously injured as a result. There has been considerable effort to reduce the mortality of commercial fishing activities on cetaceans (e.g., pingers on gillnets (Barlow and Cameron 2003)). However, there is plenty of opportunity for significant sublethal and injurious consequences from exposure to commercial gear of all types, and this type of interaction is poorly documented and understood.

To date, there have not been any spatial analyses run on the overlap between a multiple cetacean species (some of which are ESA/IUCN listed) and fishing fleets operating in the California Current Ecosystem. While reviews of the literature suggest cetacean mortality due to fishing gear interaction is low, there is a significant exposure rate and a better understanding of the spatio-temporal overlap dynamics (magnitude, seasonality and frequency) seems prudent. Therefore, it is useful to quantify the potential for overlap between commercial fishing activities and cetaceans. Moreover, comparing interspecific exposure rates to various fishing gear types may facilitate a better understanding of the risks imposed by commercial fishing activities on cetacean species.

DATA SOURCES

We overlaid two different geospatial datalayer types for these analyses: modeled cetacean density and commercial fishing effort. We compared general patterns of effort by three different commercial fleets by gear type (bottom trawl, at-sea hake midwater trawl and fixed gear fleets) with general patterns of 12 cetacean species density throughout the California Current Large Marine Ecosystem (CCLME).

CETACEAN DATA

We used estimates of cetacean density based on habitat models that were generated by the National Oceanic and Atmospheric Administration (NOAA), Southwest Fisheries Science Center for an approximate 1,141,800 km^2 study area off the U.S. west coast (Barlow et al. 2009, Forney et al. 2012). They used data from four systematic ship-based cetacean and ecosystem assessment surveys conducted in summer and fall of 1991–2001 to build habitat-based density models for 11 species and one species guild. Models were built for striped dolphin (*Stenella coeruleoalba*), short-beaked common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), northern right whale dolphin (*Lissodelphis borealis*), Dall's porpoise (*Phocoenoides dalli*), sperm whale, fin whale (*Balaenoptera physalus*), blue whale (*B. musculus*), humpback whale (*Megaptera novaeangliae*), Baird's beaked whale (*Berardius bairdii*), and a small beaked whale guild (including Cuvier's beaked whale, *Ziphius cavirostris*, and beaked whales of the genus *Mesoplodon*). Four of these species are listed as Endangered under the U.S. Endangered Species Act (Table 1). Generalized additive models (GAMs) were used to predict cetacean densities from habitat variables that included remotely sensed measures of sea surface temperature (SST) and the coefficient of variation of SST (to serve as a proxy for frontal regions); sea surface salinity, mixed layer depth (the depth at which temperature is 0.5ºC less than surface temperature), and sea surface chlorophyll collected *in situ* during the surveys; and, water depth, bathymetric slope, and distance to the 2000 m isobaths (Barlow et al. 2009, Forney et al. 2012). Model validation was performed on a novel data set (2005), and selected models were then re-fit to the complete set of 1991-2005 data. Predicted densities for each of the five individual years (1991, 1993, 1996, 2001, and 2005) were smoothed and then averaged to produce a composite grid that represents the best estimate of average cetacean density and distribution over the past 15 years. The grids were created at a resolution of approximately 25 km and covered most of the CCLME off the coast of Washington, Oregon, and California. The predicted multi-year average densities (number of animals per km^2) were used for our analyses.

COMMERCIAL FISHING EFFORT

Fishing effort was represented on either 10 km (bottom trawl fleets [herein trawl] and at-sea hake midwater trawl [herein hake] fleets) or 20 km (fixed gear fleets [herein fixed]) grids. We used data that were provided by the At-sea Hake Observer Program (A-SHOP) and the West Coast Groundfish Observer Program (WCGOP) under NOAA's Northwest Fisheries Science Center, Fishery Resource Analysis and Monitoring (FRAM) Division.

At-sea hake midwater trawl fishing effort was collected directly by the A-SHOP (National Oceanic and Atmospheric Administration 2011). The A-SHOP collects information on total catch (fish discarded and retained) from all vessels that process Pacific hake at-sea. All data were collected according to standard protocols and data quality control established by the ASHOP.

Bottom trawl fishing effort (National Oceanic and Atmospheric Administration 2010) was derived by the FRAM Division from fleet-wide logbook data submitted by state agencies to the Pacific Fisheries Information Network (PacFIN) regional database, maintained by the Pacific States Marine Fisheries Commission (PSMFC). A common-format logbook is used by Washington, Oregon, and California. Electronic logbook data is submitted by state agencies to the PacFIN regional database. Trawl logbook data is regularly used in analyses of the bottom trawl groundfish fishery observed by the WCGOP.

For both the trawl and hake survey data, a trawl towline model (line drawn from the start to end location of a trawl tow) was used to allocate data to 10 x 10 kilometer grid cells for calculation of commonly used fishing effort metrics.

Fixed gear fishing effort was collected directly by the WCGOP from the following fixed gear sectors: the limited entry sablefish primary (target – sablefish), limited entry non-sablefish endorsed (target – groundfish), open access fixed gear (target – groundfish), and Oregon and California state-permitted nearshore fixed gear (target – nearshore groundfish). The observed portion of overall fixed gear varies by coverage level in each sector (Table MMR2). Coverage rates are calculated for each sector as the observed retained catch of target species divided by the sector-wide landings of target species. Since all fishing operations are not observed, neither the maps nor the data can be used to characterize the fishery completely. Both the observed fixed gear set (start location of fishing) and haul (location of gear retrieval) were assigned to 20 x 20 kilometer grid cells for calculation. The fishing effort associated with each fixed gear fishing event was divided equally between the set and haul locations. Commonly used fishing effort metrics were then calculated for each grid cell.

There are a variety of fixed gear types recorded by WCGOP, and we used the types that we deemed most likely (based on reviews of the literature) to cause harm to a cetacean, should an individual encounter that gear type. The types we used included: historic longline, vertical hook and line, other hook and line, pot, and longline (fixed hook), longline (snap gear). We decided that both poll and troll gear did not pose a significant risk to the cetaceans in this analysis, so those two gear types were excluded from the analyses.

Fishing effort was expressed as the cumulative number of hours a given fishing fleet (trawl, hake, or fixed) had gear deployed in the water. All of the fishing effort data were reported as monthly sums for each fishing gear type, so we calculated cumulative fishing effort (in hours) from June through November of each year, which corresponded to the months over which the data were collected for building the predictive cetacean model.

For the hake and trawl fleets, the data represents all (100%) of the total fishing effort. All at-sea hake vessels (catcher-processors and motherships) over 125 feet are required to carry two observers, while vessels under 125 feet carry only one. PacFIN fleet-wide logbook data is assumed to represent the entire bottom trawl fleet for our analysis. However, all fishing operations may not necessarily be recorded in logbooks and logbook submission may not be complete. For the fixed gear fleet, observers are not present on every vessel, so we calculated a correction factor (C) in order to extrapolate the effort of the entire fixed gear fleet. Catch data are reported on an annual basis, so we ran the calculation across all years (2002-2009) by multiplying the data reported for each sector by the proportion that that sector represented over the entire study area. We used the following formula to make the calculation:

$$C = \sum_{S=1}^{4} \left(\frac{f_S}{T} \times \frac{W_{S(obs)}}{W_{S(land)}} \right)$$

where s corresponded to each of the five sectors, t was the total time (in hours) a given sector was observed with gear in the water, T was the total time (in hours) all five of the sectors were observed with gear in the water, w was the total weight of fish caught on vessels with observers present (reported by sector) and W was the total weight of fish landed on all vessels (reported by sector).

The commercial fishing effort data are subject to restrictions that preserve confidentiality as required under the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006. As such, data cannot be presented to the general public unless it represents information from three or more vessels. We ran all of the analyses in our research on the full set of fishing fleet data. However, in order to comply with confidentiality restrictions, gridcells in the final overlap maps that contained data from two or fewer boats are not displayed in this paper.

CETACEAN AND FISHERY OVERLAP

We created overlap index maps (annually and from 2002-2009) for each of the cetacean species as well as overlap index plots by year, which showed interannual variability in the overlap between the species and fleets. We also calculated the population overlap for each species with each of the three fleet types as well as a cumulative overlap index.

We used a simple formula to calculate a predicted overlap index (R, animal hours/km^2):

$$R = t*\rho$$

where t is fishing effort (total time, in hours, gear was in the water), and ρ is the predicted density of cetaceans (animals/km^2).

MAPS

We calculated the overlap indices for each year (2002 – 2009) and for each of the species and fleet type combinations (12 X 3 = 36) throughout the study area. Since the gridcell size of the cetacean data (~25 km) was not the same as the fishing effort data (10 or 20 km), we calculated an area weighted mean cumulative fishing effort for each year that corresponded to each respective cetacean gridcell. First, we combined the cetacean grid with the three fishing fleet grids using the INTERSECT command in ArcGIS (v. 9.3), a geographic information (GIS) software package developed by the Environmental Systems Research Institute (ESRI). Then, we used the information from this intersection to calculate an area weighted mean (AWM) fishing effort for each cetacean gridcell using the following equation:

$$t_{awm} = \left[\sum_{1}^{n} t_n(a_n)\right] \Big/ A$$

where t is the fishing effort in hours for a given portion of a given cetacean gridcell, a is the corresponding area for that effort and A is the total area of the corresponding cetacean gridcell. We repeated this procedure for each year (2002-2009) of the fishing fleet data.

Finally, we multiplied the AWM fishing effort, t, for each gridcell by the corresponding cetacean density (ρ), which yielded the final overlap index value. We used ArcGIS to join the corresponding predicted overlap index for each species and gear type combination to the original cetacean density grid in order to create 36 gridded maps, which we used to explore spatiotemporal patterns of cetacean and fishing fleet overlap.

DEFINITION OF RISK

We defined risk as the sensitivity of each of the 12 cetacean species to each of the three groundfish fishery fleets, if exposed. Our analyses focused on quantifying exposure and did not account for sensitivity. We will incorporate sensitivity in future IEA efforts.

ESTIMATION OF EXPOSURE

In order to estimate exposure, we multiplied the cumulative hours of fishing by the density of cetaceans (for each 25 x 25 km gridcell) for all cetacean species/fishing fleet combinations. We measured exposure in two different ways: a population overlap index, which represented what fraction of the population was exposed to each of the three fleets; and, a cumulative overlap index, which yielded spatially explicit exposure levels for each of the 25 x 25 km gridcells.

POPULATION OVERLAP INDEX

In order to compare inter- specific and fishery overlap relative to all of the modeled individuals in a given species, we calculated what fraction of each cetacean species' modeled population overlapped with areas where commercial fishing occurred using:

$$R_p = \sum_{1}^{n} \rho_x(a_n) \Big/ \sum_{1}^{n} \mathrm{P}_n(a_n)$$

where ρ is the modeled cetacean density for a given gridcell that experienced commercial fishing by a given fleet, a is the area of the corresponding gridcell, and P is the modeled cetacean density for a given gridcell, regardless of whether or not that gridcell experienced commercial fishing from any of the fleets.

CUMULATIVE OVERLAP INDEX

We calculated a cumulative overlap index over the entire study area for each cetacean species/fishing fleet combination, by year and for all years from 2002-2009 using the following equation:

$$R_c = \sum_{1}^{n} R(a_n) \Big/ A$$

where R is the predicted overlap index for a given 25 km gridcell, a_n is the area of the corresponding gridcell, and A is the total area over which a given fleet operated. This allowed us to compare patterns of inter- specific, annual, and fishery overlap.

ESTIMATION OF SENSITIVITY

We did not quantify sensitivity of the cetaceans to any of the fishing fleets. However, we intend to incorporate sensitivity in future IEA products as resources and information become available. Currently, there is limited information on the sensitivity of various cetacean species to the commercial fishing fleets that we analyzed, and incorporating that information was beyond the scope of these analyses.

RISK ASSESSMENT RESULTS

COMMERCIAL FISHING EFFORT

Overall, spatial and temporal patterns of fishing effort varied widely over the study area. The cumulative level of effort during the months of June through November from 2002 – 2009 for the fixed, hake and trawl fleets was 187,015; 24,132; and, 287,886 hours, respectively.

For the fixed gear fleet, the effort captured by observers varied across sectors (Table MMR2). In general, observers captured approximately 17.57% of the total fixed gear effort (as a function of the cumulative hours gear was deployed) that occurred over the entire study area, based on the 2002-2009 proportion of effort from each observed sector and the WCGOP coverage rate of fishery landings by sector for all years combined. WCGOP coverage rates are calculated as the observed retained weight of target species divided by the fleet-wide landed weight of target species for each sector. Therefore, the overlap indices for fixed gear fishing with the various cetacean species are likely at least five times as large as the values we presented. However, this underrepresentation would not alter the proportion of each population that overlapped with the observed fixed gear fleet. We did not correct our overlap indices to account for this underrepresentation, as we do not have information about the spatial consistency of this deficiency.

INTERANNUAL PATTERNS

Cumulative annual effort varied considerably over time for each of the fleets (Figure MMR1). Observed fixed gear cumulative efforts had peaks in 2003 and 2005, with a downward trend from 2005 to 2009 (Figure MMR1). The hake fleet gradually increased in cumulative effort level until 2008 and dropped down again in 2009 (Figure MMR1). The trawl fleet had a drop in cumulative annual fishing effort in 2004, but returned to 2002 levels of effort by 2009 (Figure MMR1).

MONTHLY INTER- AND INTRAANNUAL PATTERNS

There was considerable inter- and intraannual, and inter-fishery variability in the cumulative effort, based on the monthly data (Figure MMR2). The observed fixed gear fleets had the greatest interannual and intraannual variability in effort. This fleet generally had peak efforts during the summer months (Figure MMR2-A). However, there was usually a second peak of effort in the fall (Figure MMR2-A). Effort was lowest during the months of January, February, November and December (Figure MMR2-A). The hake fleet had the least interannual but the greatest intraannual variability in effort. The hake fleet does not fish from January to April each year, but they clearly have their maximum effort in May and June, with a smaller peak often occurring in the late fall (Figure MMR2-B). The trawl fleet had higher interannual but moderate intraannual variability in effort. The trawl fleet generally has considerable and consistent effort year round, but it tends taper towards the end of the year (Figure MMR2-C). In 2002, however, there was a strong peak of effort from October through November.

SPATIAL AND TEMPORAL PATTERNS

There was considerable inter-fishery variability in the spatial extent of cumulative effort (Figure MMR3). For the period 2002-2009, various observed fixed gear efforts occurred from the US/Mexico border, north to the US/Canada border (Figure MMR3). There were concentrations of effort off the California coastal areas of Los Angeles, San Diego, Caspar, Eureka, and the northern half of the Oregon coast (Figure MMR3). The patchy distribution of the observed fixed gear fleet is assumed to be representative of overall fishing patterns, but there is a lack of logbook or other data sources to corroborate fleet-wide spatial distribution patterns. Hake fishing efforts occurred over a much smaller region, spanning Oregon and Washington (Figure MMR3). The hake fleet was not as patchy compared with the observed fixed gear fleet, but there were areas of increased effort (Figure MMR3). The trawl fleet efforts were not quite as widespread as the observed fixed gear fleet, occurring consistently from Point Conception, CA, north to the US/Canada border (Figure MMR3). Like the hake fleet, effort was more consistent along the range of activity.

Interannual spatial variability was greatest and most patchy for the observed fixed gear fleet (figures unavailable due to confidentiality restrictions). In some years (e.g., 2002), large expanses, 100s of kms or more, had no effort whatsoever. The hake fleet also became more patchy when examined on an annual basis, but there were few large areas that were unexploited in a given year (figures unavailable due to confidentiality restrictions). The trawl fleet had the most consistent efforts over space and time of the three gear types (figures unavailable due to confidentiality restrictions). However, there was still considerable interannual variability between various 10 km gridcells.

CETACEAN AND FISHING OVERLAP MAPPING

Generally, there was low overlap spatially between the 12 cetacean species and the three commercial fishing fleets (Figures MMR4 to MMR15). Given that most of the fishing fleets operate within 100 km of shore, they overlap in a small portion of the modeled spatial domain of cetacean density.

Where there was overlap between the various cetacean species and the three commercial fishing fleets, there was considerable variation in the overlap index. Overall, cetacean species with higher modeled densities that coincided with longer durations of commercial fishing operations had higher overlap index scores.

BLUE WHALE

The highest degree of blue whale spatial overlap with WCGF fleets occurs with the observed fixed gear fleet, with some local overlap index values exceeding 20 animal hours/km^2 near San Diego, CA and just north of Cape Mendocino, CA (Figure MMR4). Overlap with the trawl fleet is much lower, with a few overlap indices exceeding ~4 animal hours/km^2 near Cape Mendocino, CA and off of the San Francisco Bay, CA (Figure MMR4). Overlap with the hake fleet was very limited, an was <0.5 animal hours/km^2 in all locations (Figure MMR4).

FIN WHALE

The highest areas of fin whale spatial overlap with the WCGF occur from the Columbia River area northward, with overlap indices for the observed fixed gear fleet of >20 animal hours/km^2 near the Columbia River mouth, and indices for the trawl fleet >3 animal hours/km^2 along the Washington coast (Figures MMR5). The highest overlap index with the hake fleet was < 2 animal hours/km^2, off the northern Washington coast (Figure MMR5).

BAIRD'S BEAKED WHALE

The observed fixed gear fleet overlapped the most (Figure MMR6) with Baird's beaked whale (>3.1 animal hours/km^2) near the mouth of the Columbia River, the Stonewall Bank, OR, and the Trinidad Canyon, CA. Overlap with the hake fleet was considerably lower, with maxima occurring just west of Ozette Island, WA (0.239 animal hours/km^2, Figure MMR6). For the trawl fleet, overlap was generally higher in the northern two thirds of the fishing grounds, with maxima occurring just west of Ozette Island, WA, and north of Cape Mendocino, CA (>0.65 animal hours/km^2, Figure MMR6)

SHORT-BEAKED COMMON DOLPHIN

Short-beaked common dolphins overlapped the most with the fixed gear fleet from south of the Channel Islands, CA down to the US/Mexico border (>1,076 animal hours/km^2, Figure MMR7). Overlap with the hake fleet was greatest just west of Ozette Island, WA, near the mouth of the Columbia River and near the Astoria Sea Channel, OR (>17 animal hours/km^2, Figure MMR7). The trawl fleet overlapped fairly consistently along the entire fishing area, with maximum overlap occurring just west of Ozette Island, WA, just north of Cape Mendocino, CA and off the coast of San Francisco, CA (>83 animal hours/km^2, Figure MMR7).

RISSO'S DOLPHIN

The observed fixed gear fleet overlap with Risso's dolphin was greatest near the mouth of the Columbia River, the Stonewall Bank, OR, just north of Cape Mendocino, CA, and from the Northeast Bank, CA south to the US/Mexico border (>129 animal hours/km^2, Figure MMR8). Overlap with the hake fleet was greatest just west of Ozette Island, WA, and over the stretch from the mouth of the Columbia River south to the Stonewall Bank, OR, (>7 animal hours/km^2, Figure MMR8). Maximal overlap with the trawl fleet occurred over farily large areas near Ozette Island, WA, and in a fairly large area at the Columbia River plume (>23 animal hours/km^2, Figure MMR8).

PACIFIC WHITE-SIDED DOLPHIN

Pacific white-sided dolphin overlap with the observed fixed gear fleet occurred near the mouth of the Columbia River, the Stonewall Bank, OR, and near Trinidad Canyon, CA (>289 animal hours/km^2, Figure MMR9). Overlap with the hake and trawl fleets was most pronounced near Neah Bay, WA (>28 and >128 animal hours/km^2, respectively, Figure MMR9).

NORTHERN RIGHT WHALE DOLPHIN

Maximum overlap between northern right whale dolphin and the observed fixed gear fleet occurred near the mouth of the Columbia River and Trinidad Canyon, OR (>115 animal hours/km^2, Figure MMR10). The hake fleet overlapped the most near Neah Bay, WA (>9 animal hours/km^2, Figure MMR10), and trawl fleet efforts overlapped the most near Neah Bay, WA, but had a pretty consistent overlap all the way south to Cape Mendocino and beyond (33 animal hours/km^2, Figure MMR10).

HUMPBACK WHALE

For the observed fixed gear fleet, peak areas of overlap with humpback whales (>17 animals hours/km^2) occur north of Cape Mendocina, CA off the central Oregon coast, and off the Columbia River mouth (Figure MMR11). For the trawl fleet, the highest overlap indices occur along the northern portion of the coast from Cape Mendocina, CA to Cape Flattery, WA with areas of overlap > 3 animals hours/km^2 (Figure MMR11). The highest overlap indices for the hake fleet occur near Cape Flattery, WA and are < 2 animal hours/km^2 (Figure MMR11)

DALL'S PORPOISE

Overlap with the observed fixed gear fleet and Dall's porpoises was concentrated from the mouth of the Columbia River south to around the Stonewall Bank, OR (>630 animal hours/km^2, Figure MMR12). Maximum overlap with the hake fleet was near Neah Bay, WA, and in the region from the Columbia River plume south to around Heceta Valley, OR (>40 animal hours/km^2, Figure MMR12). The trawl fleet overlapped fairly consistently from Neah Bay, WA, all the way south to Cape Mendocino, CA (>124 animal hours/km^2, Figure MMR12).

SPERM WHALE

Overlap indices between the sperm whale distribution and the groundfish fisheries are generally lower compared with other whales. For the observed fixed gear fleet, the maximum values are < 6 animal hours/km^2, and occur in only a few places north of Cape Mendocino, CA (Figure MMR13). Overlap indices for the trawl fleet are fairly low and uniform from San Francisco, CA to Cape Flattery, WA and generally < 1 animal hours/km^2 (Figure MMR13). Overlap indices for the hake fleet are all < 0.3 animal hours/km^2 (Figure MMR13).

STRIPED DOLPHIN

Striped dolphin overlapped most with the observed fixed gear fleet near the mouth of the Columbia, Stonewall Bank, OR, Trinidad Canyon, CA, and over a fairly large area running south of Cape Mendocino down to just north of the Cordell Bank (>3 animal hours/km^2, Figure MMR14). In contrast, overlap with the hake fleet was concentrated over a fairly large area from the mouth of the Columbia River south to the Oregon/California border (>0.06 animal hours/km^2, Figure MMR14). Overlap with the trawl fleet was also fairly homogeneous, and was consistently high from 45° N latitude south to Santa Lucia Bank, CA (>0.7 animal hours/km^2, Figure MMR14)

SMALL BEAKED WHALES

Maximum observed fixed gear fleet overlap with small beaked whales occurred in the Columbia River plume, Stonewall Bank, OR, and the Trinidad Canyon, CA Vizcaino Knoll, and off San Diego, CA (>11 animal hours/km^2, Figure MMR15). Overlap coincided the most with hake fleet efforts that occurred near Neah Bay, WA, the mouth of the Columbia River and the Stonewall Bank, OR (>0.6 animal hours/km^2, Figure MMR15). Finally, trawl fleet operations overlapped the most near Neah Bay, WA, the Columbia River plume, Stonewall Bank, OR, Siltcoos Bank, OR, Trinidad Canyon, CA, south of Cape Mendocino, CA, and off the coast of San Francisco, CA (>2 animal hours/km^2, Figure MMR15).

POPULATION OVERLAP INDEX

There was considerable variability in the proportion of each modeled cetacean population that overlapped with the three fleet types for the years 2002-2009 (Figure MMR16, top panel). Overall, humpback whale, Dall's porpoise and Pacific white-sided dolphin had the greatest proportion of their populations overlapping with each of the three fleets. Population overlap was generally highest for the observed trawl fleet, but not always (i.e., short-beaked common and Risso's dolphin, Figure MMR16, top panel). It's important to note that the proportions displayed by the bars in Figure MMR16 (top panel) cannot be summed, as there was overlap between the different fleet types.

CUMULATIVE OVERLAP INDEX

OVERALL PATTERNS

Overall, there were marked differences in the overlap indices of the different cetacean species (Figure MMR16, bottom panel). The largest overlap indices occurred in the observed fixed gear fleet, which were about 40 times that of the hake fleet and 2.5 times that of the trawl fleet. Short-beaked common dolphin had the highest overlap index when combining all of fleets and Baird's beaked and sperm whales, and striped dolphin had the lowest (Figure MMR16, bottom panel). Within the three fleets, there was considerable variability in the overlap indices with dolphins and porpoises experiencing the highest overlap indices, while whales had the lowest overlap values (Figure MMR16, bottom panel).

INTERANNUAL PATTERNS

As was the case with the overall cumulative overlap indices, there was considerable interspecific variation (Figure MMR17). Overall, cumulative overlap indices (COI) were higher for the observed fixed gear fleet, compared with the hake and trawl fleets. For the observed fixed gear fleet, many cetacean species (Dall's porpoise, Pacific white-sided dolphin, northen right whale dolphin, Risso's dolphin) had marked increases in their COI in 2003 and 2005, and most species, with the exception of short-beaked common dolphin, generally had a lower COI in 2009 compared with 2002. Short-beaked common dolphin show a strong increase in the COI from 2002 from 2009, rising nearly 10 fold during this time period. Cumulative overlap indices for most species increased consistently from 2003-2008 for the hake fleet, but dropped off markedly in 2009 (Figure MMR17B). Dall's porpoise, short-beaked common dolphin and Pacific white-sided dolphin consistently had the greatest COI of all the 12 modeled cetacean species, whereas Baird's beaked whale, blue whale, fin whale, humpback whale, sperm whale, striped dolphin and small beaked whales had the lowest COI (Figure MMR17B). Finally, the trawl fleet COI were markedly different from the observed fixed gear and hake fleets. Aside from 2004, COI values were fairly consistent over time, or slightly declining (e.g., short-beaked common dolphin, Figure MMR17C). The COI for all 12 cetacean species was significantly lower in 2004, with around 20 – 30% decreases occurring in most species.

LIMITATIONS AND NEXT STEPS

There were many limitations to this risk assessment, but we focus on four broad categories that we feel were the most important and warrant the greatest attention for future improvements on this risk assessment. Those categories were: spatial and temporal scaling, indirect groundfish fishery impacts, vulnerability vs. sensitivity, and other sources of risk.

SPATIAL AND TEMPORAL SCALING

Our approach for assessing the relative overlap between cetaceans and groundfish fleets was to compare cumulative fishing effort over all areas fished from 2002 – 2009, with best estimates of cetacean density over the past 15 years in the CCLME. Cetacean survey data are collected every 3 to 4 years, so we believe that comparing specific survey years (e.g., 2005 and 2008) with the corresponding fishing effort year might provide insight on interannual variability of overlap. Unfortunately, other scaling related problems are less easily addressed. For example, fishing effort data are available at the individual vessel level, which provides monthly, seasonal and annual patterns of effort, with high spatial and temporal precision. Acquiring comparable data for 12 species of cetaceans would require radiotagging and tracking thousands of animals, which would be logistically intractable. Therefore, generating overlap comparisons at this fine of a scale is not possible with current information, so we rely on other proxies of exposure or risk.

INDIRECT IMPACTS

Impacts from commercial fisheries on cetaceans can be direct ("operational" as described by Beverton (1985)) or indirect. Direct impacts include vessel collisions (Panigada et al. 2006), entanglement with fishing gear and "bycatch" (Lien 1994, Reeves et al. 2003, Read et al. 2006, Young and Ludicello 2007), stress (Curry 1999, Fair and Becker 2000), noise (National Research Council 2003, Romano et al. 2004, Nowacek et al. 2007), and toxins such as hydrocarbons, exhaust, etc. (Jarman et al. 1996, Marsili et al. 2001). Indirect effects of commercial fishing include exploitation competition and habitat disturbance (Dayton et al. 1995, Bearzi et al. 1999, DeMaster et al. 2001, DeMaster et al. 2006, Herr et al. 2009). While it appears as though direct impacts of the groundfish fleets on cetaceans (via bycatch and vessel collisions) are minimal at a population level (Jannot et al. 2011), indirect impacts are poorly understood. This is particularly the case with the fixed gear fleet, where observer coverage only averages about 17% across all the gear types (Table MMR2). Given the coarse nature of our analyses, it is difficult to be certain that "overlap" or "exposure", as we have defined it, would result in harm to a given cetacean species. Rather, our analyses provide relative risks, in that some species have greater exposure to certain gear types, and certain gear types present a greater potential risk, compared with others.

Future risk analyses of the groundfish fleets should formally take in to account indirect effects from all three of the fleets considered in these analyses. However, quantifying these effects is difficult and complex, which is probably why they have not been exhaustively analyzed in the past. Further, devising better ways to estimate the potential for harm, given overlap in any given 625 km^2 grid cell, would greatly improve future risk assessments.

VULNERABILITY VS. SENSITIVITY

Rowe (1977) argued that risk is the probability that something harmful will occur, and one quantifies that probability in a risk assessment. The first step in assessing this probability is identifying vulnerability or the exposure of an organism to something that could be harmful. In this analysis, we quantified the potential risk imposed by three commercial fishing fleets on cetaceans by taking the product of cetacean density and commercial fishing effort. This was not a formal risk assessment where changes in population growth were calculated as a function of a given fishing influence. This could be viewed as a "relative" risk assessment, in that we calculated the overlap of exposure to the various fleet types. Using a common currency of fishing effort expressed as time and cetacean density expressed as the mean number of animals predicted to occupy a given area each year. We did not explicitly address the two most common aspects of as risk assessment: vulnerability and sensitivity (Zacharias and Gregr 2005). However, we argue that our analyses directly addressed vulnerability, in that a given cetacean species is vulnerable to the potential negative consequences of a given fishing fleet type when it is in fact exposed to the vessels and gear from that fleet. While further work on the sensitivity of these species to the stressors induced by commercial fishing activities is needed for a formal risk assessment, our analyses are an important first step in characterizing the spatio-temporal patterns of cetacean exposure or vulnerability to commercial fishing fleets in the California Current.

OTHER SOURCES OF RISK

There are many risks to cetacean populations occurring in the CCLME in addition to the groundfish fishery fleets. These risks include other commercial fishing fleets (e.g., drift- and gillnet fleets), anthropogenic stress (Curry 1999, Fair and Becker 2000), collisions with non-fisheries vessels (Laist et al. 2001, Jensen and Silber 2003), noise (Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals 2003, Romano et al. 2004), exposure to toxins (hydrocarbons, exhaust, etc. (Jarman et al. 1996, Marsili et al. 2001)), entanglement with marine debris (Williams et al. 2011), resource competition (Trites et al. 1997, Herr et al. 2009, Gomez-Campos et al. 2011) and habitat disturbance from fishing (Kaiser 1998, Watling and Norse 1998), and global climate change (MacLeod 2009). While this list is not exhaustive, it provides context for the range of risks that cetacean are confronted with. Quantifying the vulnerability and sensitivity of cetaceans to these threats is an important next step in running a more comprehensive risk assessment.

FUTURE RISK ANALYSES

Integrating the three aforementioned broad categories would greatly improve our ability to more comprehensively run risk assessments for cetaceans occurring in the CCLME. We were unable to address these deficiencies, given limitations of resources and time, and given the lack of available data for many of the aforementioned potential risks. Given the scarcity of data available for running comprehensive risk assessments for cetaceans in the CCLME, adopting the strategies laid out by Samhouri and Levin (2012), might be a productive first step towards a more quantitative and comprehensive risk assessment. An example of an application of this methodology is described in detail in the "Risk Assessment for Habitats in the Monterey Bay National Marine Sanctuary" section of this IEA. This approach calculates "relative risk" as a function of various "drivers and pressures" or stressors, accounts for data quality, and can incorporate disparate types of quantitative data. This would be an ideal next step for cetacean risk assessments and would provide valuable insight into the deficiencies that might be preventing a more formal and comprehensive risk assessment. Finally, studies directed at quantifying the risk imposed by stressors not considered in our assessment would be beneficial if we wish to improve our certainty regarding the risks imposed on cetaceans by various anthropogenic stressors found in the CCLME.

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FIGURE LEGENDS

Figure MMR1. Interannual trends in fishing effort, expressed as cumulative number of hours per year (June through November months, 2002-2009) fishing gear was deployed in the water for each of the three fleet types.

Figure MMR2. Monthly trends in fishing effort, expressed as cumulative number of hours per month (from 2002-2009) fishing gear was deployed in the water for each of the three fleet types. Panel A = fixed; Panel B = hake; and, Panel C = trawl.

Figure MMR3. Patterns of fishing effort along the west coast of the United States, expressed as cumulative number of hours per gridcell (all months from 2002-2009) fishing gear was deployed in the water for each of the three fleet types.

Figure MMR4. Left map: modeled blue whale mean density expressed as the number of individuals/yr/km^2 (based on survey data collected from 1991 – 2005) within the EEZ off the west coast of the United States. Three narrow maps: overlap values for blue whale with the fixed, hake and trawl fleets.

Figure MMR5. Left map: modeled fin whale mean density expressed as the number of individuals/yr/km^2 (based on survey data collected from 1991 – 2005) within the EEZ off the west coast of the United States. Three narrow maps: overlap values for fin whale with the fixed, hake and trawl fleets.

Figure MMR6. Left map: modeled Baird's beaked whale mean density expressed as the number of individuals/yr/km^2 (based on survey data collected from 1991 – 2005) within the EEZ off the west coast of the United States. Three narrow maps: overlap values for Baird's beaked whale with the fixed, hake and trawl fleets.

Figure MMR7. Left map: modeled short-beaked common dolphin mean density expressed as the number of individuals/yr/km^2 (based on survey data collected from 1991 – 2005) within the EEZ off the west coast of the United States. Three narrow maps: overlap values for short-beaked common dolphin with the fixed, hake and trawl fleets.

Figure MMR8. Left map: modeled Risso's dolphin mean density expressed as the number of individuals/yr/km^2 (based on survey data collected from 1991 – 2005) within the EEZ off the west coast of the United States. Three narrow maps: overlap values for Risso's dolphin with the fixed, hake and trawl fleets.

Figure MMR9. Left map: modeled Pacific white sided dolphin mean density expressed as the number of individuals/yr/km^2 (based on survey data collected from 1991 – 2005) within the EEZ off the west coast of the United States. Three narrow maps: overlap values for Pacific white sided dolphin with the fixed, hake and trawl fleets.

Figure MMR10. Left map: modeled Northern right whale dolphin mean density expressed as the number of individuals/yr/km^2 (based on survey data collected from 1991 – 2005) within the EEZ off the west coast of the United States. Three narrow maps: overlap values for Northern right whale dolphin with the fixed, hake and trawl fleets.

Figure MMR11. Left map: modeled humpback whale mean density expressed as the number of individuals/yr/km^2 (based on survey data collected from 1991 – 2005) within the EEZ off the west coast of the United States. Three narrow maps: overlap values for humpback whale with the fixed, hake and trawl fleets.

Figure MMR12. Left map: modeled Dall's porpoise mean density expressed as the number of individuals/yr/km^2 (based on survey data collected from 1991 – 2005) within the EEZ off the west coast of the United States. Three narrow maps: overlap values for Dall's porpoise with the fixed, hake and trawl fleets.

Figure MMR13. Left map: modeled sperm whale mean density expressed as the number of individuals/yr/km^2 (based on survey data collected from 1991 – 2005) within the EEZ off the west coast of the United States. Three narrow maps: overlap values for sperm whale with the fixed, hake and trawl fleets.

Figure MMR14. Left map: modeled striped dolphin mean density expressed as the number of individuals/yr/km^2 (based on survey data collected from 1991 – 2005) within the EEZ off the west coast of the United States. Three narrow maps: overlap values for striped dolphin with the fixed, hake and trawl fleets.

Figure MMR15. Left map: modeled small beaked whales mean density expressed as the number of individuals/yr/km^2 (based on survey data collected from 1991 – 2005) within the EEZ off the west coast of the United States. Three narrow maps: overlap values for small beaked whales with the fixed, hake and trawl fleets.

Figure MMR16. Modeled proportion (upper) and cumulative exposure index (lower) of each cetacean species population that overlaped with each of the three commercial fishing fleets (from 2002-2009), for each of the 12 cetacean species. B ba = Baird's beaked whale; B mu = blue whale; B ph = fin whale; D de = short-beaked common dolphin; G gr = Risso's dolphin; L bo = northern right whale dolphin; L ob = Pacific white-sided dolphin; M no = humpback whale; P da = Dall's porpoise; P ma = sperm whale; S co = striped dolphin; and, Zsm = small beaked whales.

Figure MMR17. Cumulative annual commercial fishing fleet overlap indices (from 2002-2009) for each of the 12 cetacean species. Panels A, B, and C are the fixed, hake and trawl fleets, respectively. B ba = Baird's beaked whale; B mu = blue whale; B ph = fin whale; D de = short-beaked common dolphin; G gr = Risso's dolphin; L bo = northern right whale dolphin; L ob = Pacific white-sided dolphin; M no = humpback whale; P da = Dall's porpoise; P ma = sperm whale; S co = striped dolphin; and, Zsm = small beaked whales.

Table MMR1. Twelve species of cetaceans represented in predicted cetacean density geospatial datalayer (Barlow and Forney 2007, Barlow et al. 2009).

Cetacean	**Suborder**	**Family**	**ESA Status**	**IUCN**
Baird's beaked whale (*Berardius bairdii*)	Odontoceti (toothed)	Ziphiidae (beaked)		Data Deficient
Blue whale (*Balaenoptera musculus*)	Mysticeti (baleen)	Balaenopteridae	Endangered	EN
Fin whale (*B. physalus*)	Mysticeti (baleen)	Balaenopteridae	Endangered	EN
Short-beaked common dolphin (*Delphinus delphis*)	Odontoceti (toothed)	Delphinidae (dolphins)		LC
Risso's dolphin (*Grampus griseus*)	Odontoceti (toothed)	Delphinidae (dolphins)		LC
Northern right whale dolphin (*Lissodelphis borealis*)	Odontoceti (toothed)	Delphinidae (dolphins)		LC
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	Odontoceti (toothed)	Delphinidae (dolphins)		LC
Humpback whale (*Megaptera novaeangliae*)	Mysticeti (baleen)	Balaenopteridae	Endangered	LC
Dall's porpoise (*Phocoenoides dalli*)	Odontoceti (toothed)	Phocoenidae (porpoises)		LC
Sperm whale (*Physeter macrocephalus*)	Odontoceti (toothed)	Physeteridae (sperm whales)	Endangered	VU
Striped dolphin (*Stenella coeruleoalba*)	Odontoceti (toothed)	Delphinidae (dolphins)		LC
Small beaked whales (*Ziphius* and *Mesoplodon*)	Odontoceti (toothed)	Ziphiidae (beaked)		LC

EN = endangered; LC = least concern; VU = vulnerable;

Table MMR2. Fixed gear fishing effort represented in West Coast Groundfish Observer Program (WCGOP) data by sector observed; including the proportion of total observed effort (cumulative hours gear was deployed) by sector from 2002-2009, the observed sector coverage rate calculated as the observed retained catch weight of target species divided by the fleet-wide landed weight of target species, and the assumed proportion of total fleet-wide effort represented in the observed data.

Sector (2002-2009)	% of Total Duration by Sector	Sector Coverage Rate	Proportion of Duration Represented
Limited Entry Sablefish Primary	59.38%	26.12%	15.51%
Limited Entry Non-Tier-Endorsed Fixed Gear	17.00%	7.41%	1.26%
Open Access Fixed Gear	18.63%	3.00%	0.56%
Oregon Nearshore Fixed Gear	3.83%	5.20%	0.20%
California Nearshore Fixed Gear	1.16%	3.43%	0.04%

Sum total percentage of duration represented = 17.57%

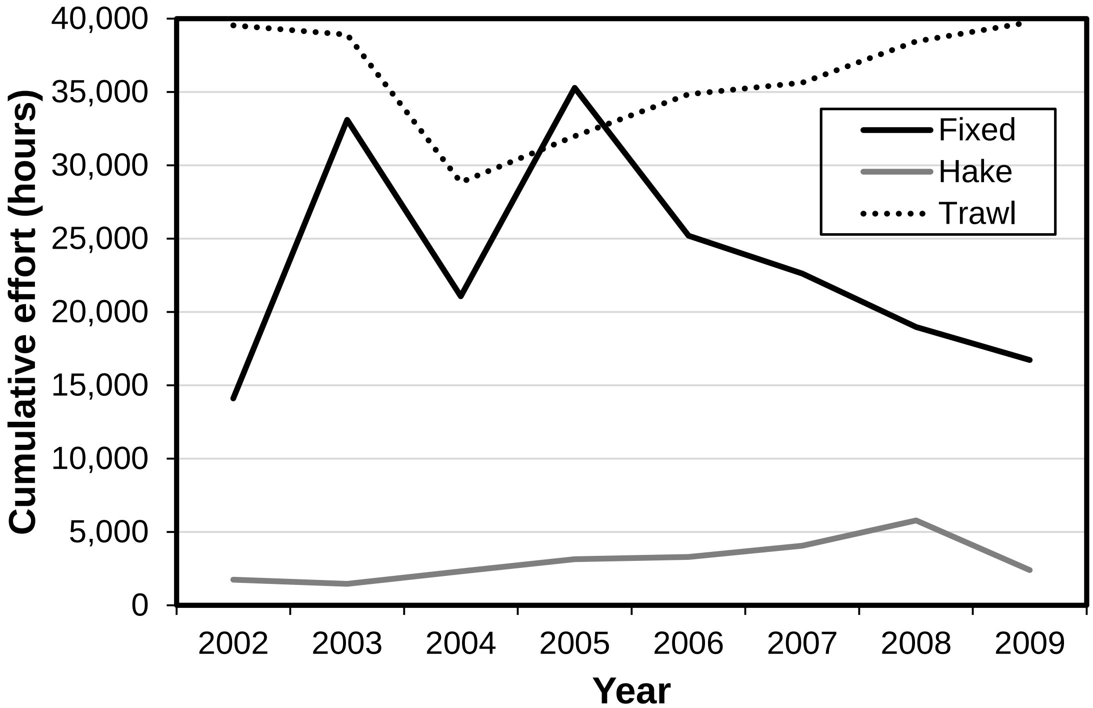

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Cumulative effort (hours)
2002
2003
2004
2005
2006
2007
2008
2009
Year
Fixed
Hake
Trawl

Figure MMR1

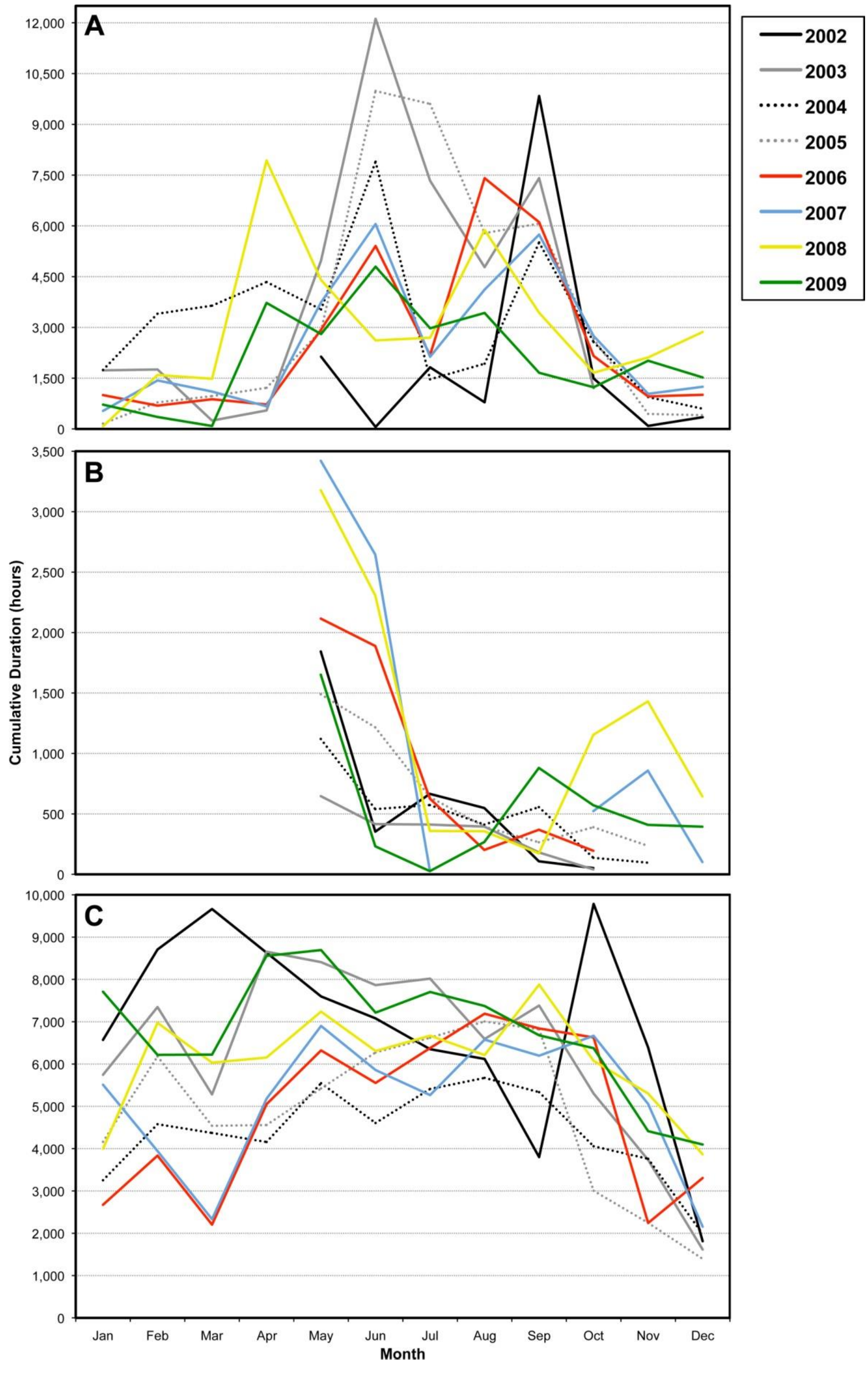
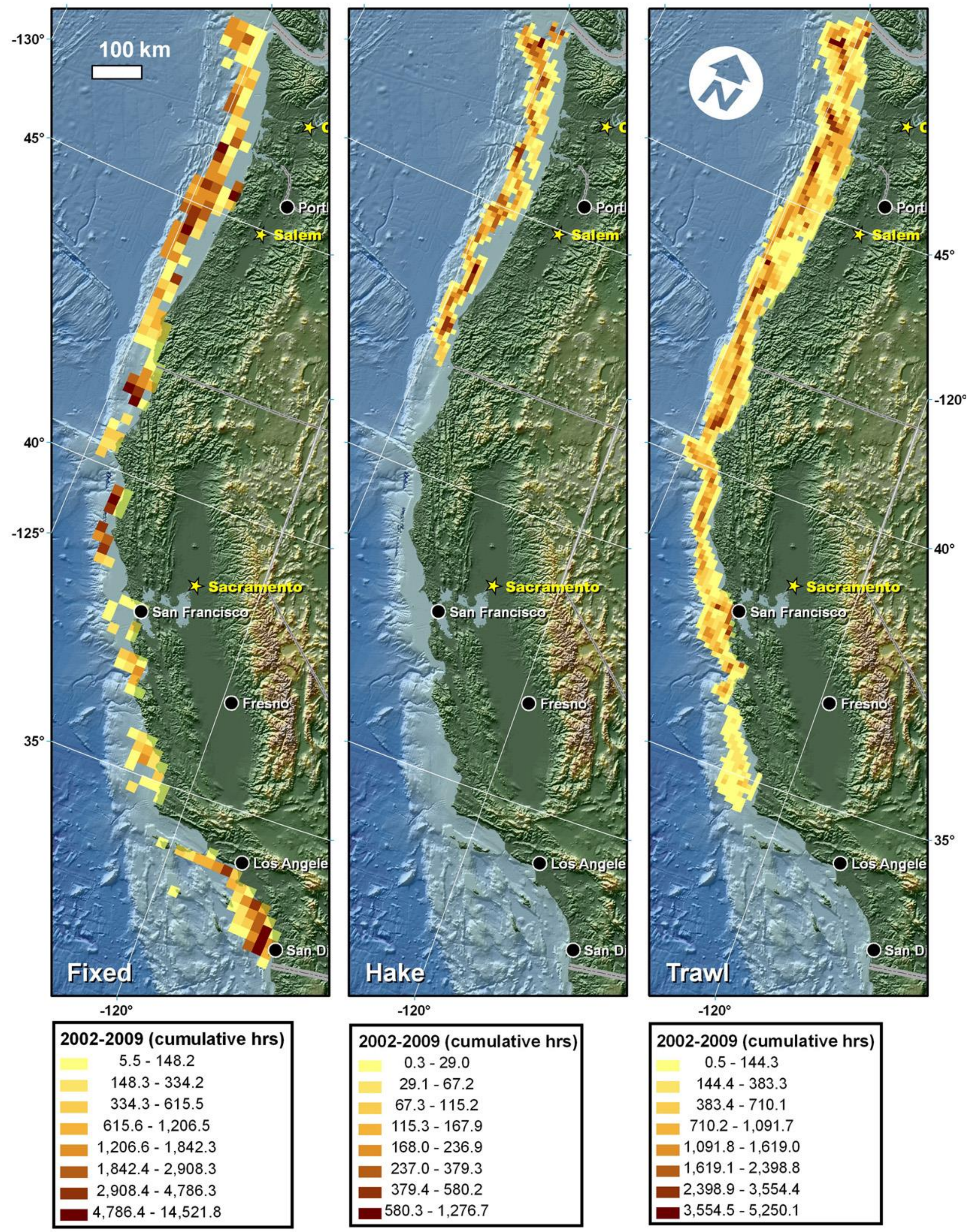
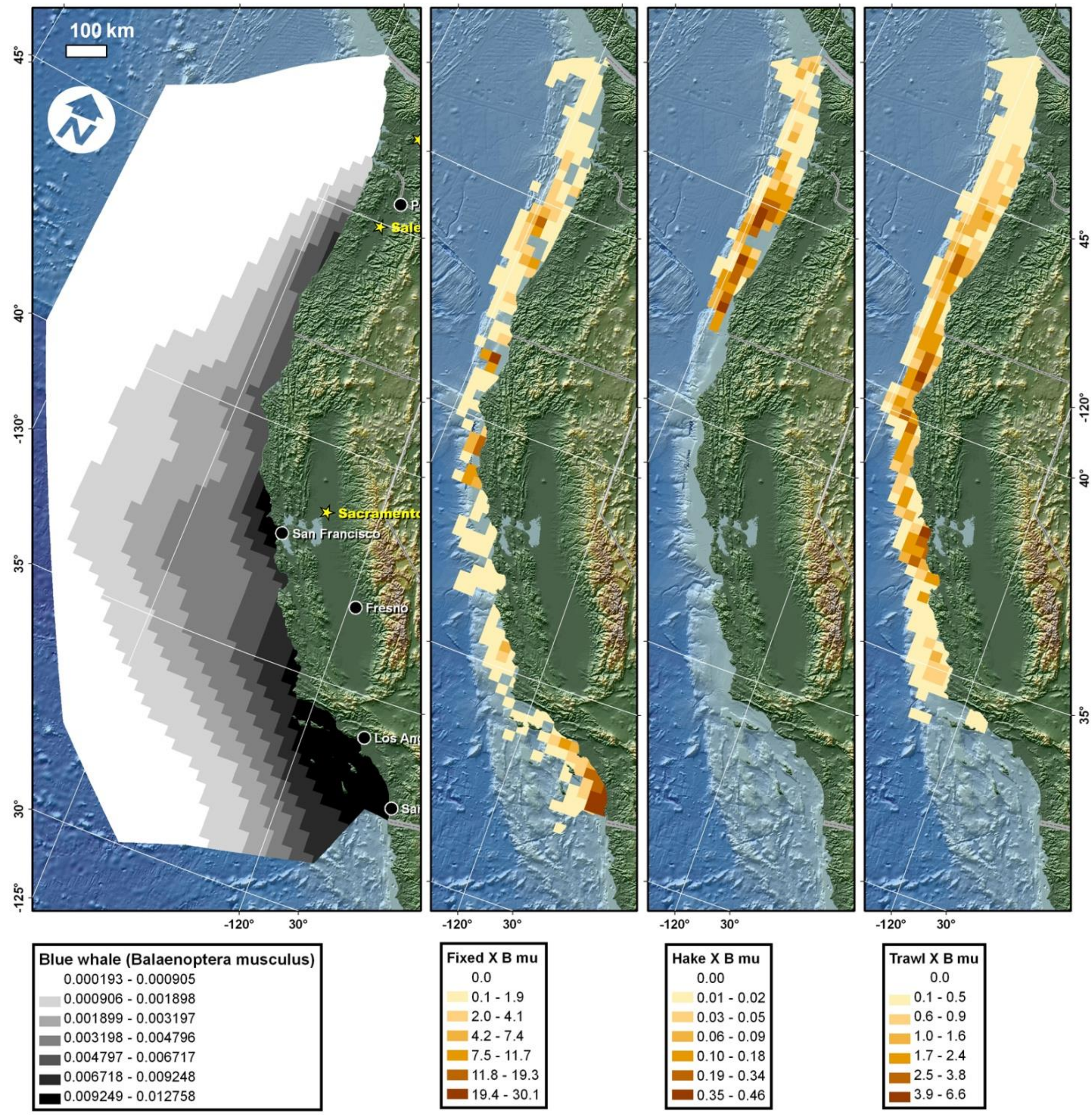

A
B
C
2002
2003
2004
2005
2006
2007
2008
2009
12,000
10,500
9,000
7,500
6,000
4,500
3,000
1,500
0
3,500
3,000
2,500
2,000
1,500
1,000
500
0
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Cumulative Duration (hours)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure MMR2



100 km
-130°
45°
40°
-125°
35°
-120°
Port
Salem
Sacramento
San Francisco
Fresno
Los Angele
San D
Fixed
Hake
Trawl
-120°
45°
40°
35°
2002-2009 (cumulative hrs)
5.5 - 148.2
148.3 - 334.2
334.3 - 615.5
615.6 - 1,206.5
1,206.6 - 1,842.3
1,842.4 - 2,908.3
2,908.4 - 4,786.3
4,786.4 - 14,521.8
2002-2009 (cumulative hrs)
0.3 - 29.0
29.1 - 67.2
67.3 - 115.2
115.3 - 167.9
168.0 - 236.9
237.0 - 379.3
379.4 - 580.2
580.3 - 1,276.7
2002-2009 (cumulative hrs)
0.5 - 144.3
144.4 - 383.3
383.4 - 710.1
710.2 - 1,091.7
1,091.8 - 1,619.0
1,619.1 - 2,398.8
2,398.9 - 3,554.4
3,554.5 - 5,250.1

Figure MMR3



100 km
N
45°
40°
35°
30°
-130°
-125°
-120°
30°
-120°
45°
40°
35°
Sacramento
San Francisco
Fresno
Blue whale (Balaenoptera musculus)
0.000193 - 0.000905
0.000906 - 0.001898
0.001899 - 0.003197
0.003198 - 0.004796
0.004797 - 0.006717
0.006718 - 0.009248
0.009249 - 0.012758
Fixed X B mu
0.0
0.1 - 1.9
2.0 - 4.1
4.2 - 7.4
7.5 - 11.7
11.8 - 19.3
19.4 - 30.1
Hake X B mu
0.00
0.01 - 0.02
0.03 - 0.05
0.06 - 0.09
0.10 - 0.18
0.19 - 0.34
0.35 - 0.46
Trawl X B mu
0.0
0.1 - 0.5
0.6 - 0.9
1.0 - 1.6
1.7 - 2.4
2.5 - 3.8
3.9 - 6.6

Figure MMR4

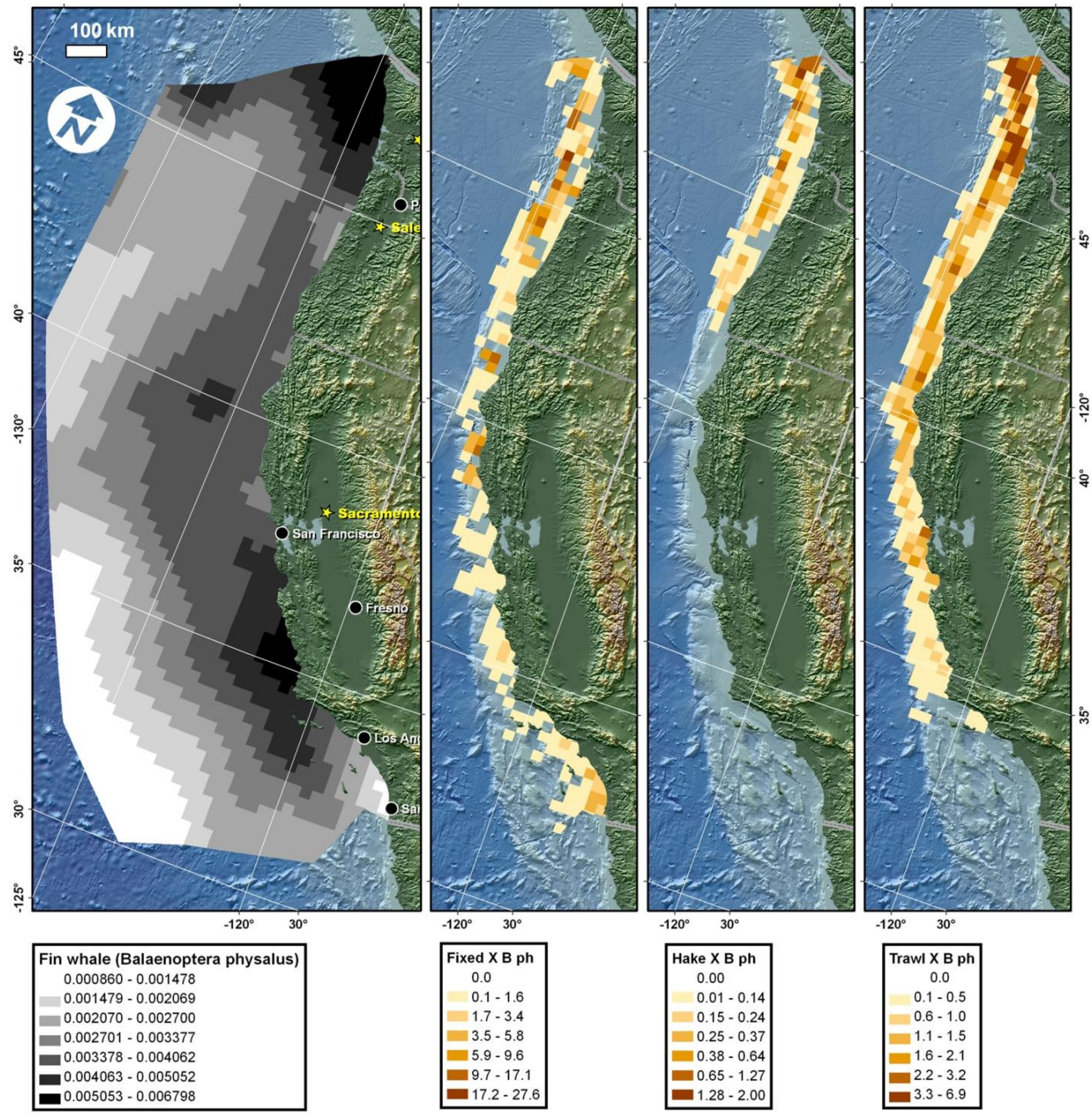

100 km
Salem
Sacramento
San Francisco
Fresno
Los Angeles
45°
40°
35°
30°
-130°
-125°
-120°
30°
Fin whale (Balaenoptera physalus)
0.000860 - 0.001478
0.001479 - 0.002069
0.002070 - 0.002700
0.002701 - 0.003377
0.003378 - 0.004062
0.004063 - 0.005052
0.005053 - 0.006798
Fixed X B ph
0.0
0.1 - 1.6
1.7 - 3.4
3.5 - 5.8
5.9 - 9.6
9.7 - 17.1
17.2 - 27.6
Hake X B ph
0.00
0.01 - 0.14
0.15 - 0.24
0.25 - 0.37
0.38 - 0.64
0.65 - 1.27
1.28 - 2.00
Trawl X B ph
0.0
0.1 - 0.5
0.6 - 1.0
1.1 - 1.5
1.6 - 2.1
2.2 - 3.2
3.3 - 6.9

Figure MMR5

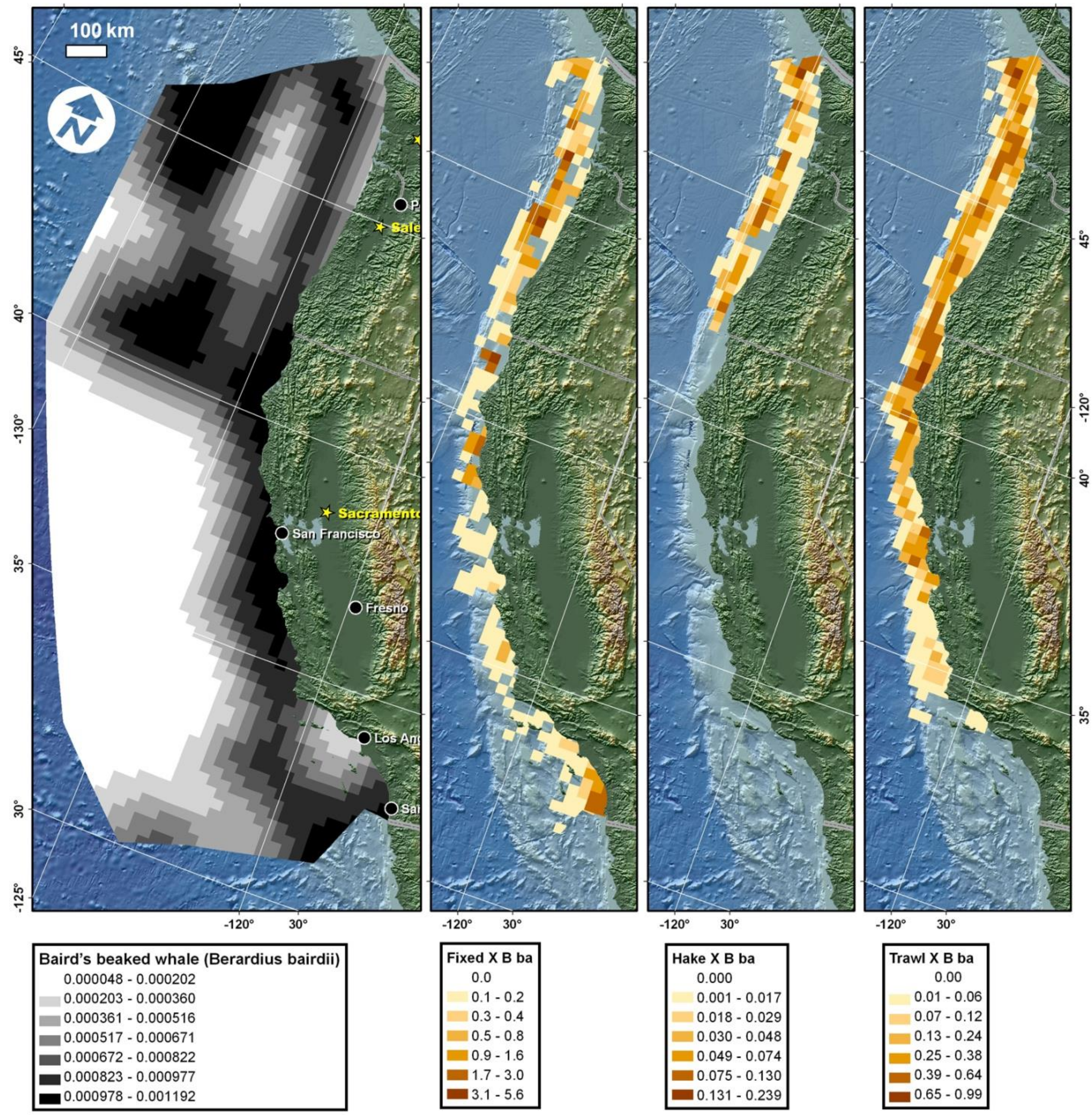

100 km
Sacramento
San Francisco
Fresno
Baird's beaked whale (Berardius bairdii)
0.000048 - 0.000202
0.000203 - 0.000360
0.000361 - 0.000516
0.000517 - 0.000671
0.000672 - 0.000822
0.000823 - 0.000977
0.000978 - 0.001192
Fixed X B ba
0.0
0.1 - 0.2
0.3 - 0.4
0.5 - 0.8
0.9 - 1.6
1.7 - 3.0
3.1 - 5.6
Hake X B ba
0.000
0.001 - 0.017
0.018 - 0.029
0.030 - 0.048
0.049 - 0.074
0.075 - 0.130
0.131 - 0.239
Trawl X B ba
0.00
0.01 - 0.06
0.07 - 0.12
0.13 - 0.24
0.25 - 0.38
0.39 - 0.64
0.65 - 0.99

Figure MMR6

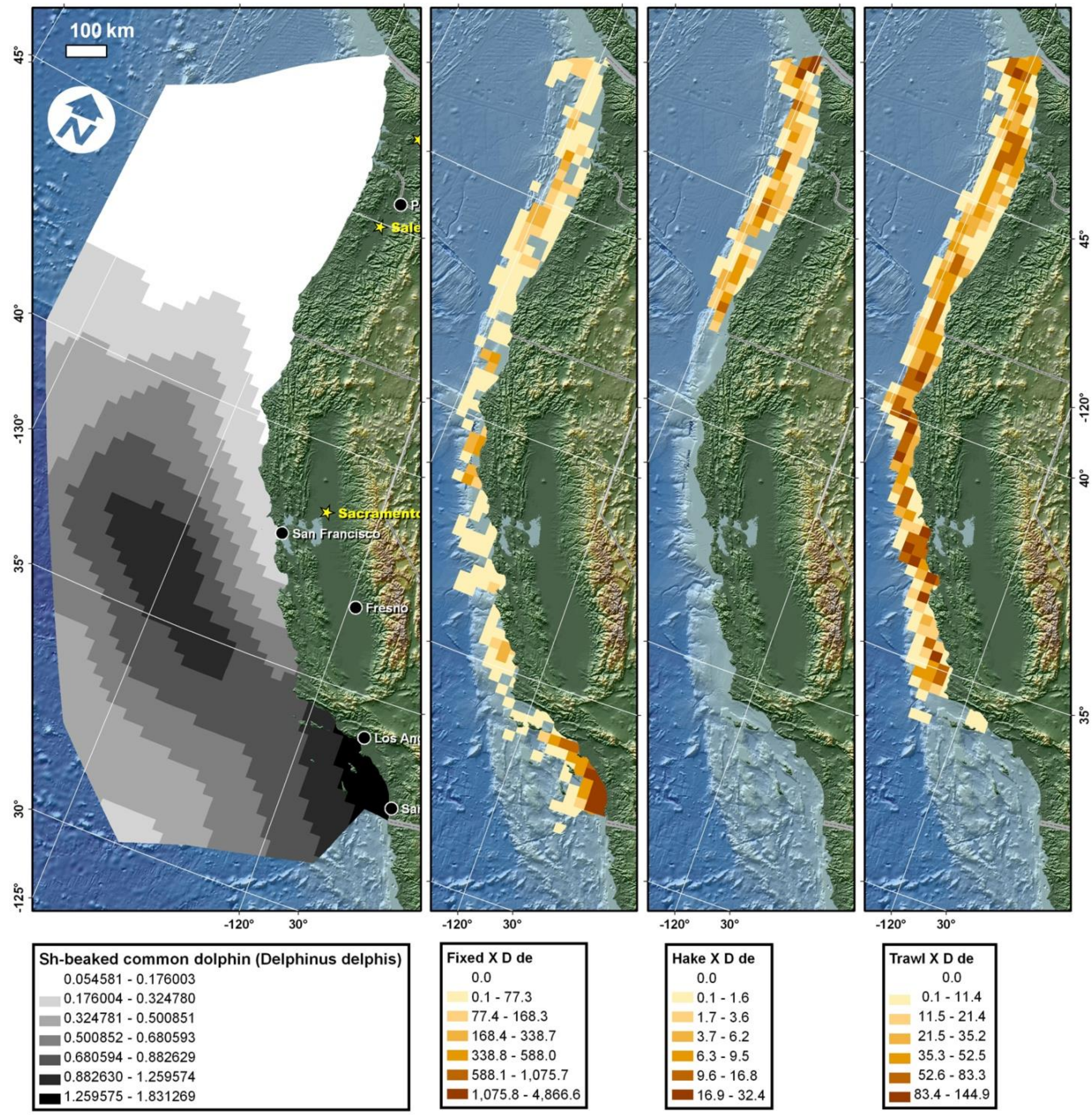

100 km
San Francisco
Sacramento
Fresno
45°
40°
35°
30°
-130°
-125°
-120°
30°
Sh-beaked common dolphin (Delphinus delphis)
0.054581 - 0.176003
0.176004 - 0.324780
0.324781 - 0.500851
0.500852 - 0.680593
0.680594 - 0.882629
0.882630 - 1.259574
1.259575 - 1.831269
Fixed X D de
0.0
0.1 - 77.3
77.4 - 168.3
168.4 - 338.7
338.8 - 588.0
588.1 - 1,075.7
1,075.8 - 4,866.6
Hake X D de
0.0
0.1 - 1.6
1.7 - 3.6
3.7 - 6.2
6.3 - 9.5
9.6 - 16.8
16.9 - 32.4
Trawl X D de
0.0
0.1 - 11.4
11.5 - 21.4
21.5 - 35.2
35.3 - 52.5
52.6 - 83.3
83.4 - 144.9

Figure MMR7

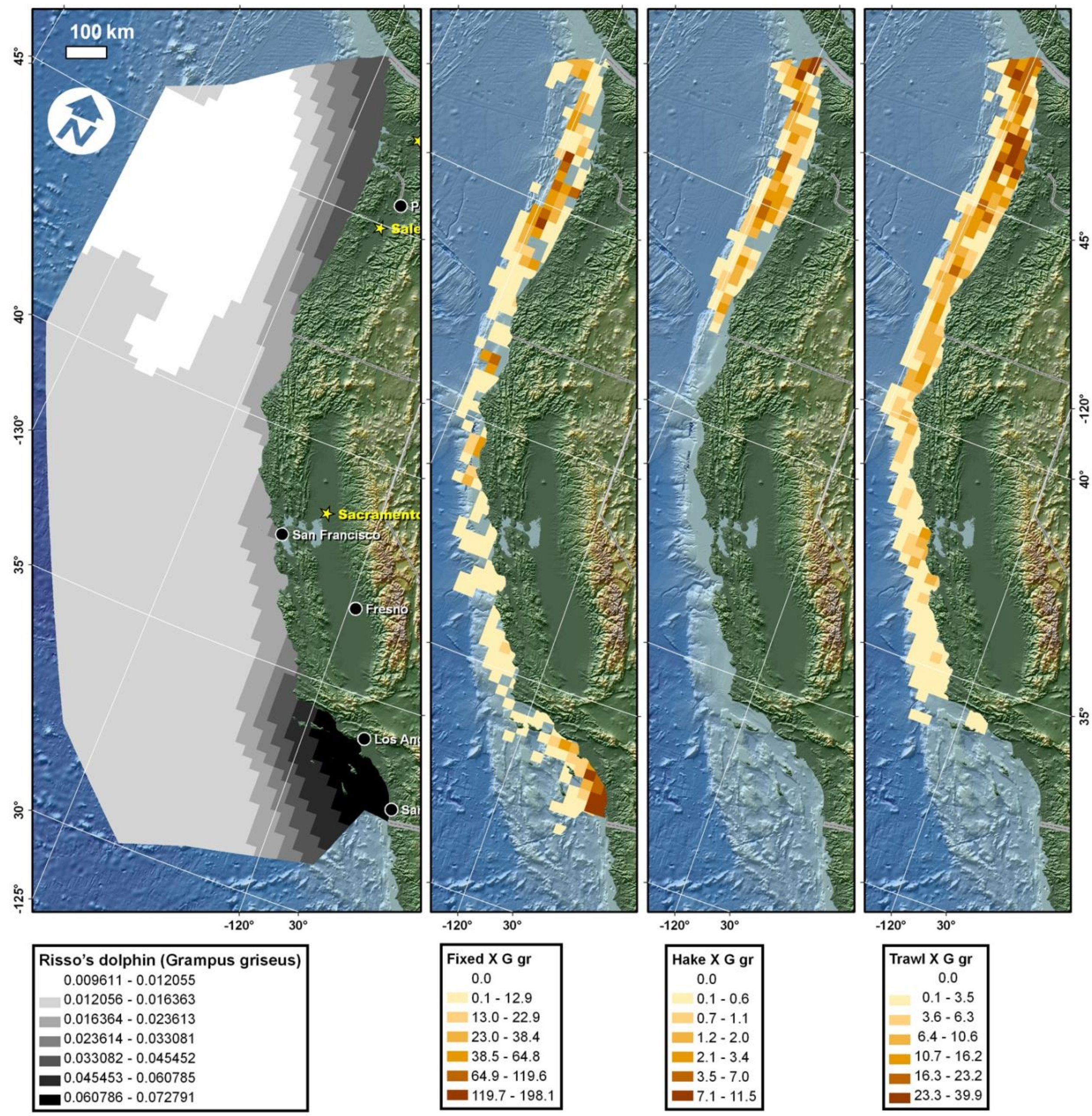

100 km
45°
40°
-130°
35°
30°
-125°
-120°
30°
San Francisco
Sacramento
Fresno
Risso's dolphin (Grampus griseus)
0.009611 - 0.012055
0.012056 - 0.016363
0.016364 - 0.023613
0.023614 - 0.033081
0.033082 - 0.045452
0.045453 - 0.060785
0.060786 - 0.072791
Fixed X G gr
0.0
0.1 - 12.9
13.0 - 22.9
23.0 - 38.4
38.5 - 64.8
64.9 - 119.6
119.7 - 198.1
Hake X G gr
0.0
0.1 - 0.6
0.7 - 1.1
1.2 - 2.0
2.1 - 3.4
3.5 - 7.0
7.1 - 11.5
Trawl X G gr
0.0
0.1 - 3.5
3.6 - 6.3
6.4 - 10.6
10.7 - 16.2
16.3 - 23.2
23.3 - 39.9

Figure MMR8

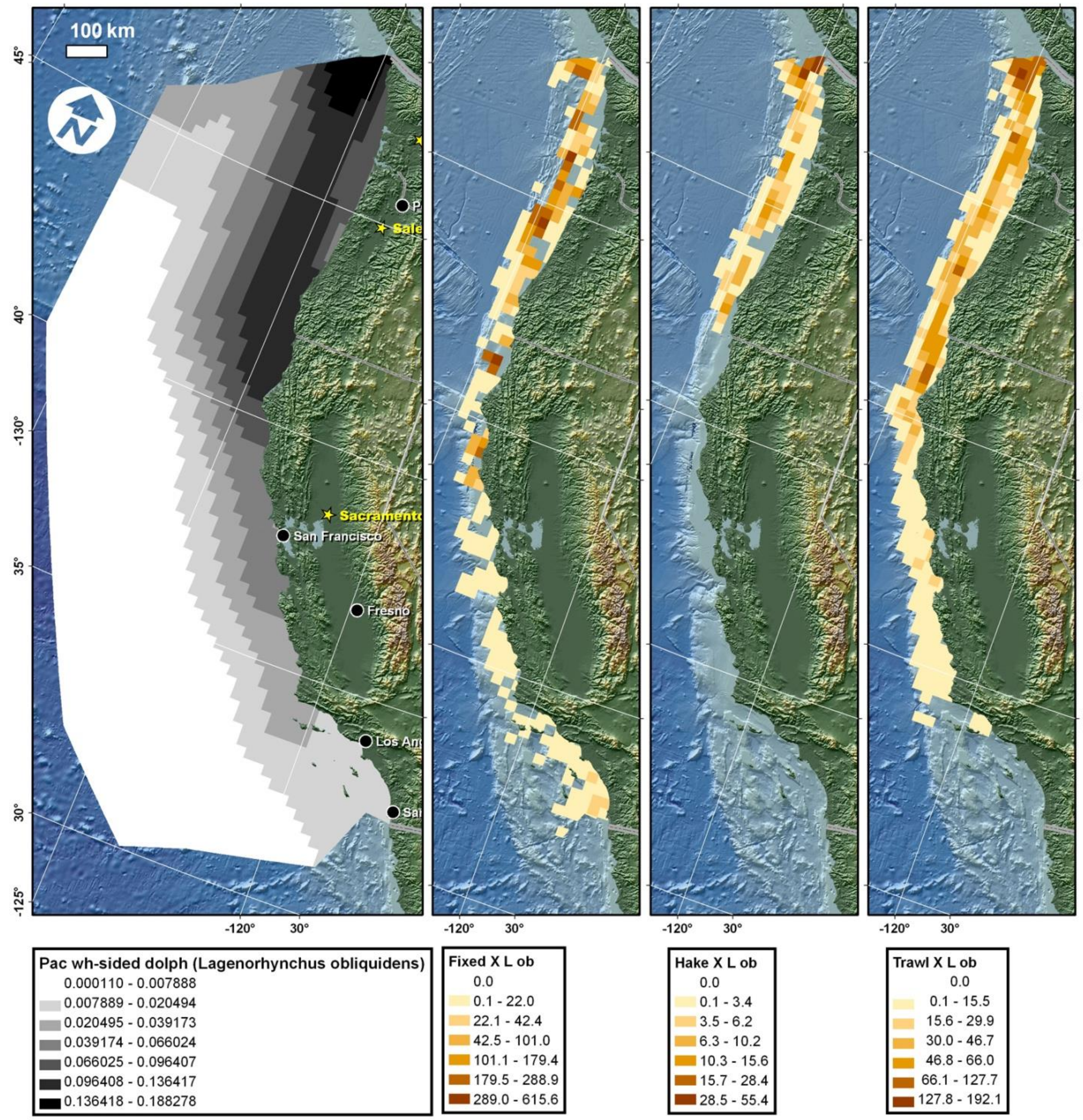

100 km
Sacramento
San Francisco
Fresno
Pac wh-sided dolph (Lagenorhynchus obliquidens)
0.000110 - 0.007888
0.007889 - 0.020494
0.020495 - 0.039173
0.039174 - 0.066024
0.066025 - 0.096407
0.096408 - 0.136417
0.136418 - 0.188278
Fixed X L ob
0.0
0.1 - 22.0
22.1 - 42.4
42.5 - 101.0
101.1 - 179.4
179.5 - 288.9
289.0 - 615.6
Hake X L ob
0.0
0.1 - 3.4
3.5 - 6.2
6.3 - 10.2
10.3 - 15.6
15.7 - 28.4
28.5 - 55.4
Trawl X L ob
0.0
0.1 - 15.5
15.6 - 29.9
30.0 - 46.7
46.8 - 66.0
66.1 - 127.7
127.8 - 192.1

Figure MMR9

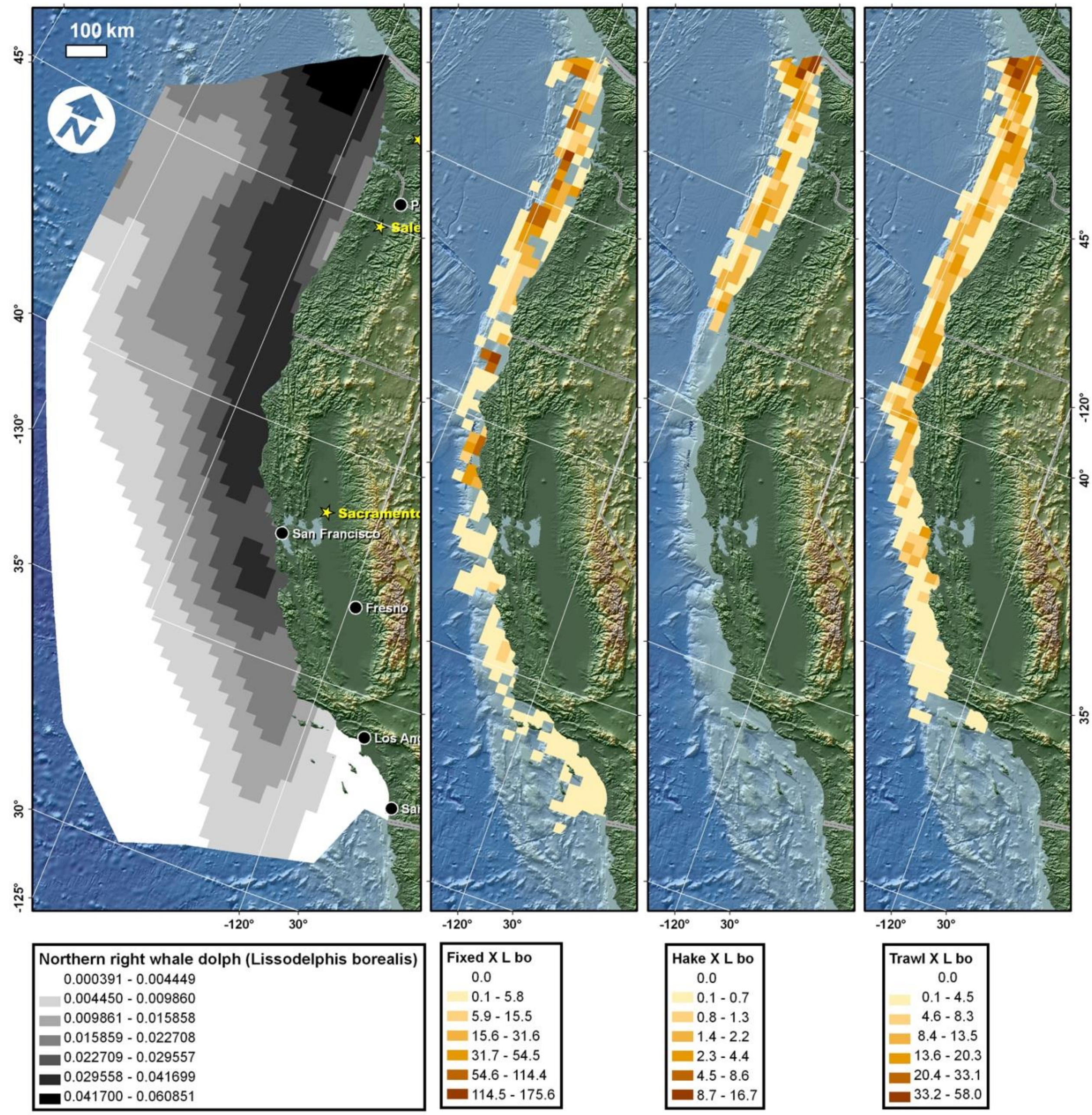


Figure MMR10

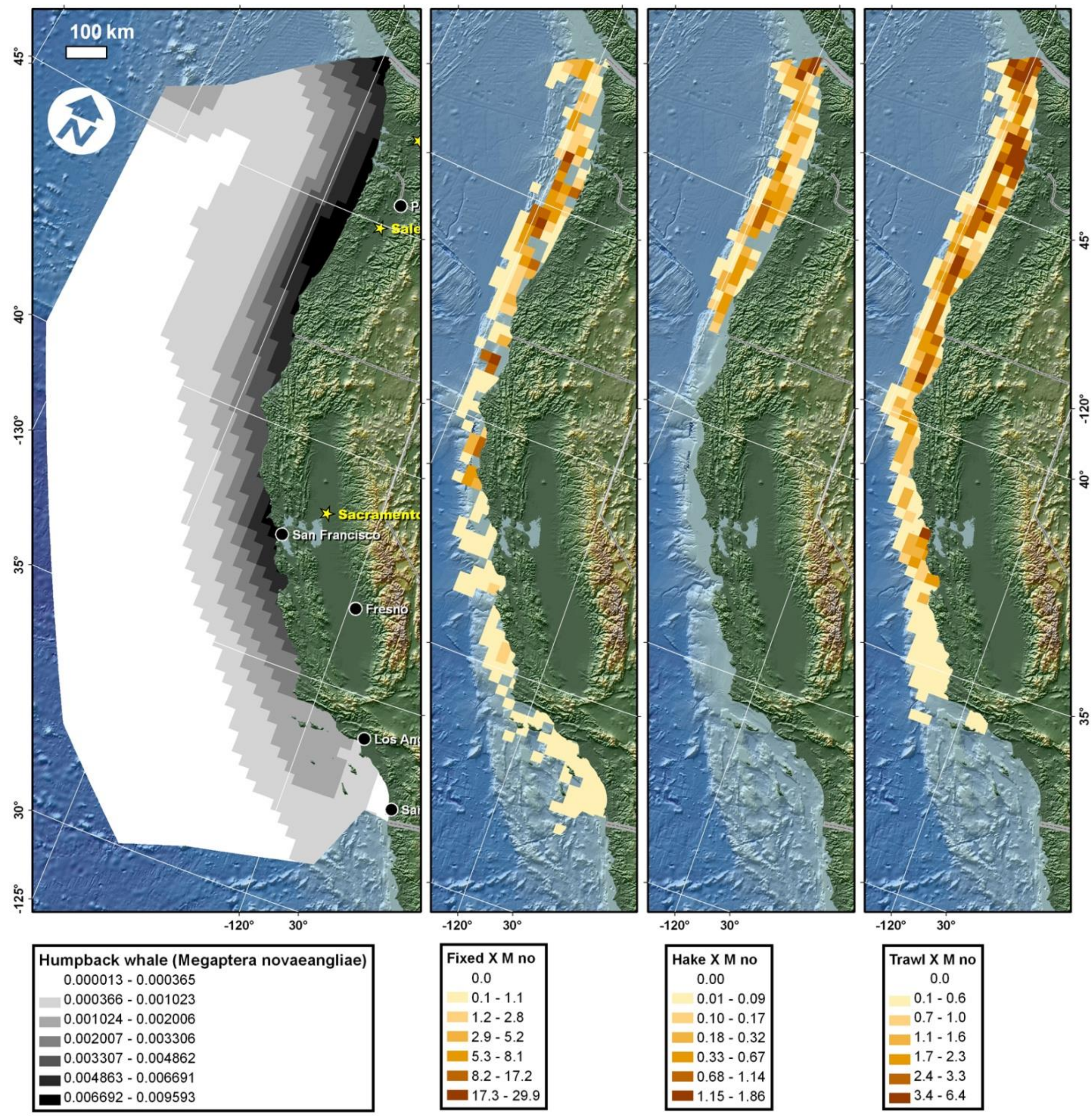


Figure MMR11

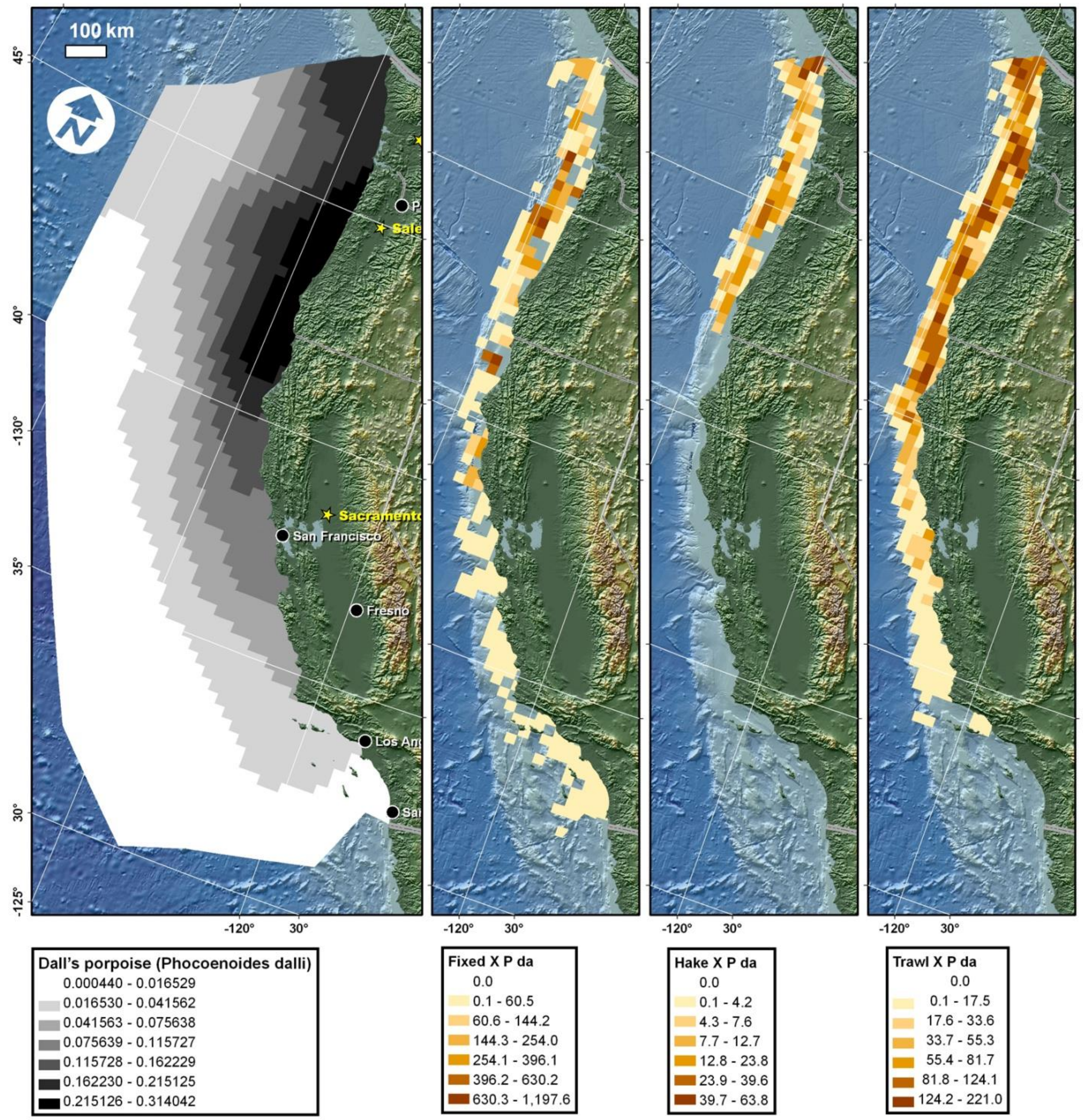


Figure MMR12

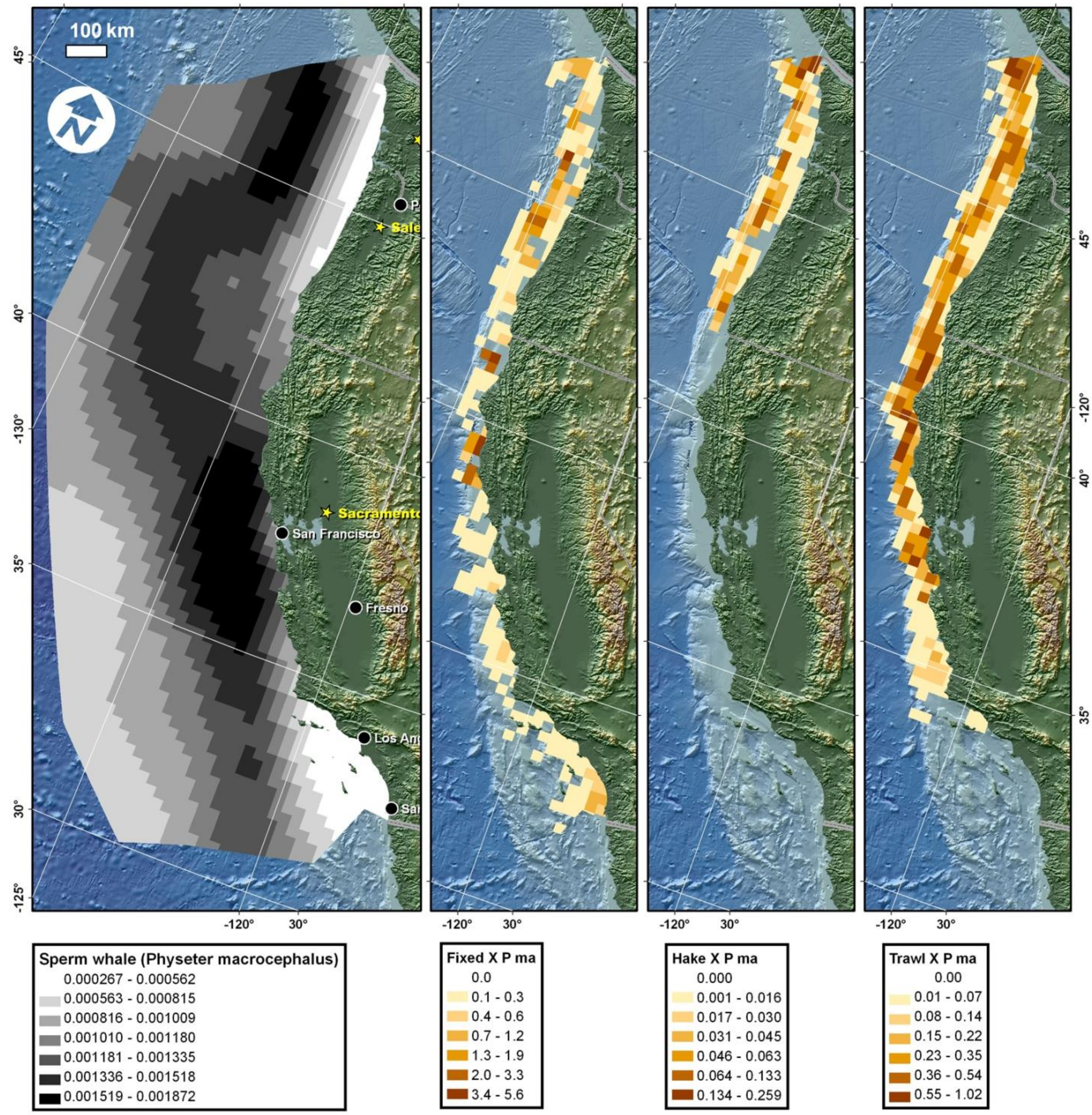


Figure MMR13

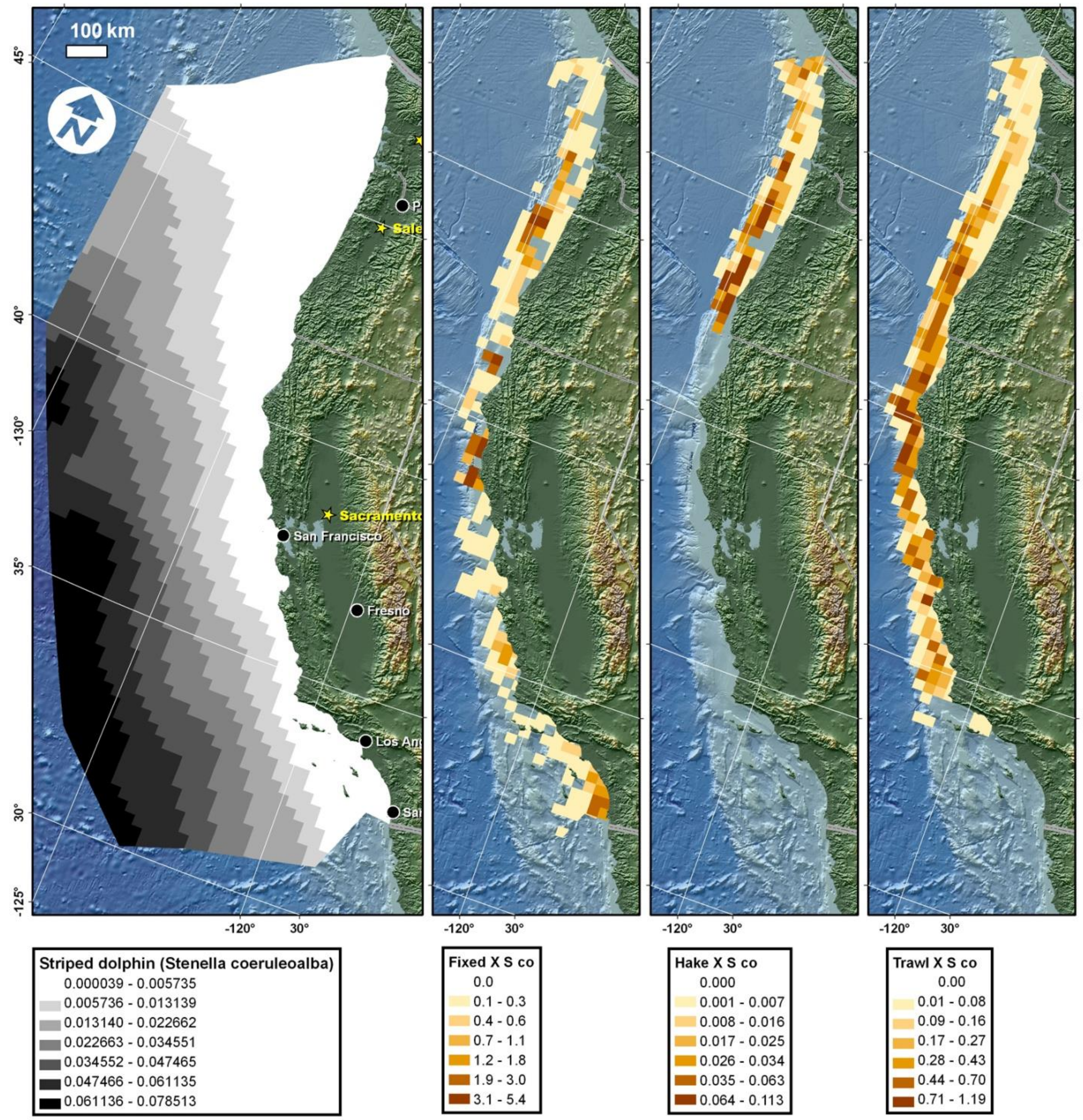


Figure MMR14

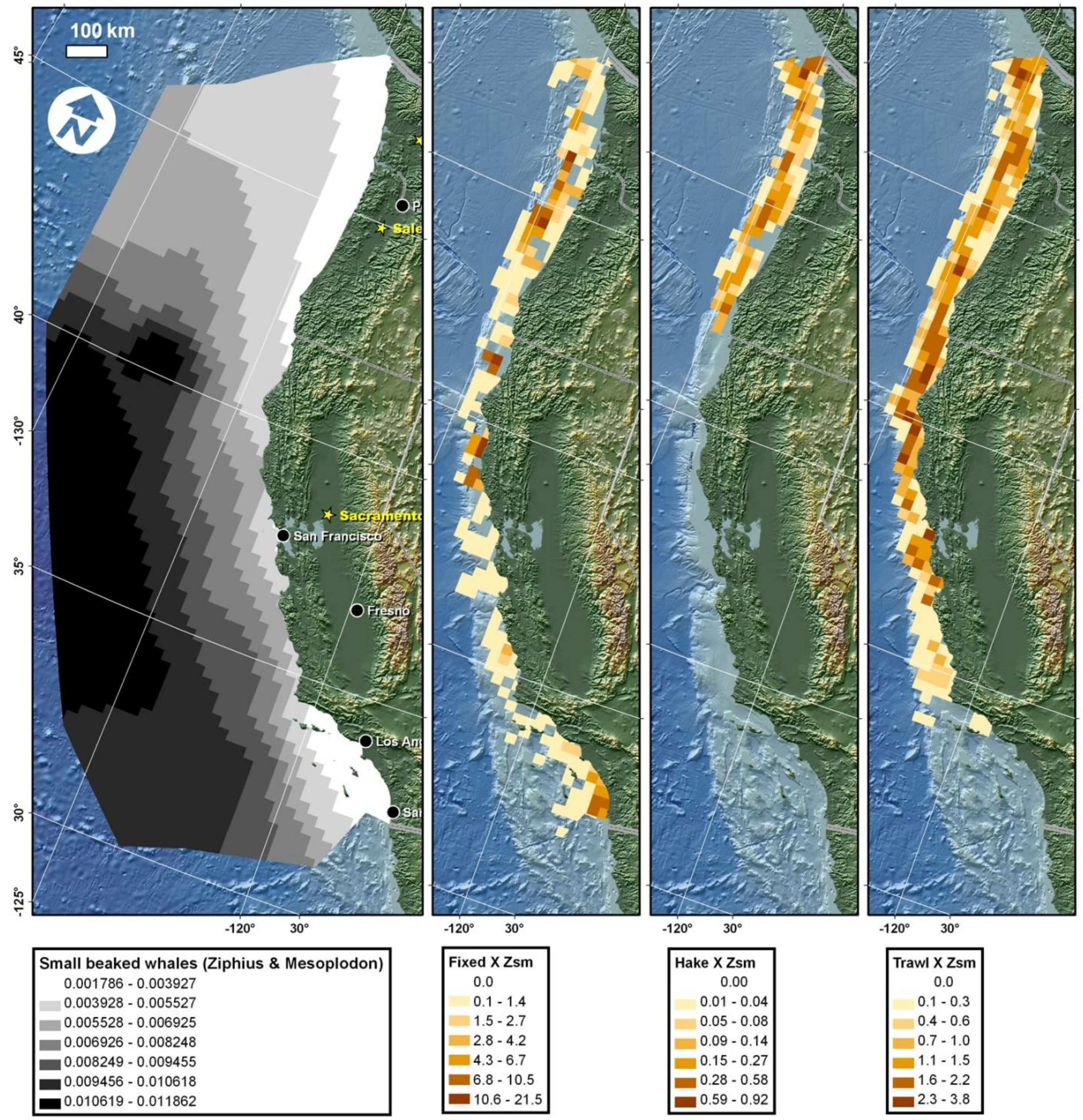


Figure MMR15

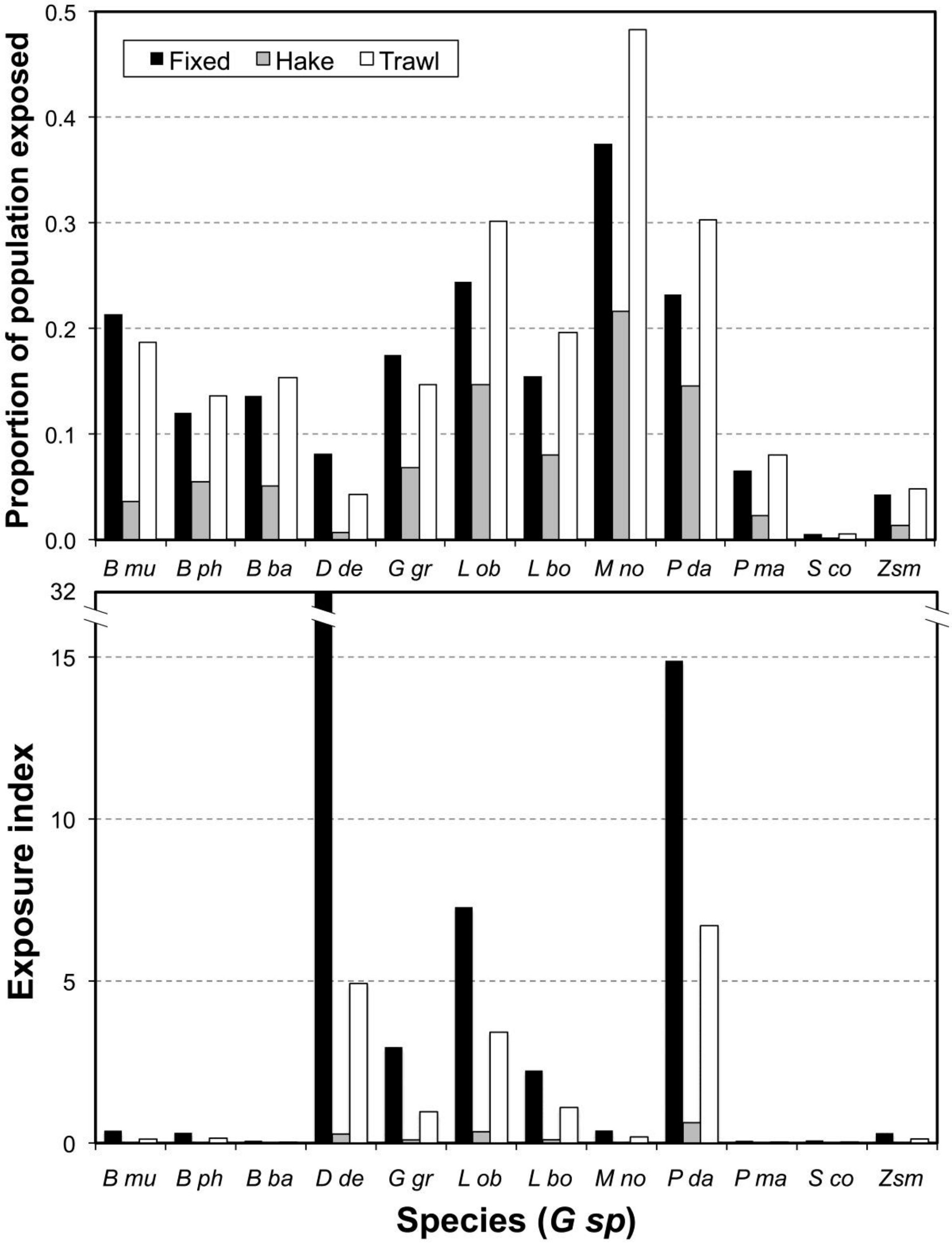


Figure MMR16

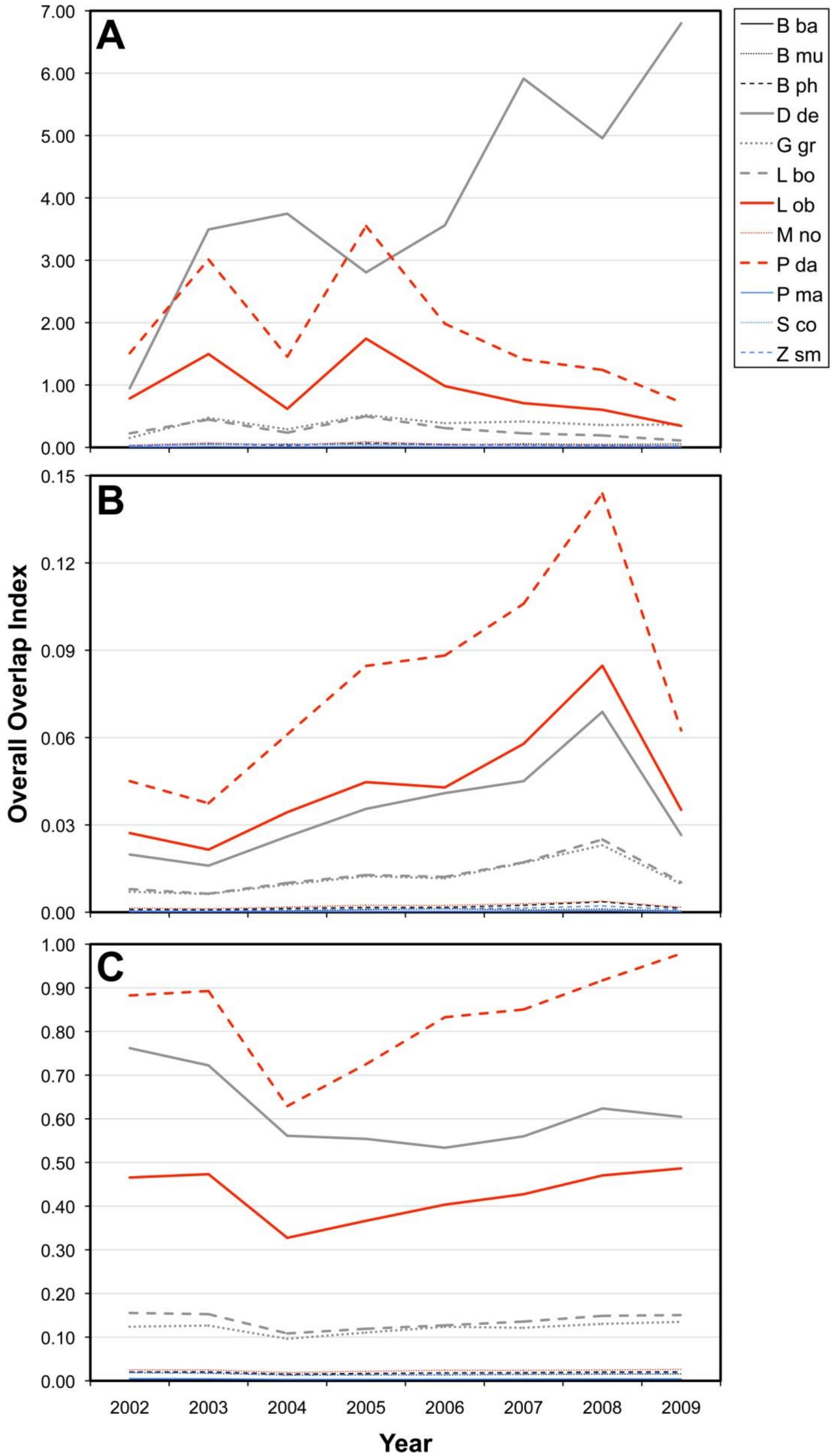


Figure MMR17