Risk assessment of U.S. West Coast groundfish fisheries to threatened and endangered marine species[1]

January 13, 2012

[1] This report should be cited as: Northwest Fisheries Science Center. 2011. Risk assessment of U.S. West Coast groundfish fisheries to threatened and endangered marine species. Northwest Fisheries Science Center, National Marine Fisheries Service. 2725 Montlake Blvd E, Seattle, WA.

Acknowledgements

This report was prepared by staff from the NWFSC Conservation Biology and Fishery Resource Analysis and Monitoring Divisions and the NMFS Northwest Region Sustainable Fisheries Division.   Specific contributors include:

Marlene Bellman (FRAMD; fishery description, spatial analysis)
Steve Copps (SFD; fishery description)
Candice Emmons (CBD; whales)
Jon Drake (CBD, turtles)
Blake Feist (CBD, spatial analysis)
Michael Ford (CBD; whales, birds, turtles)
Tom Good (CBD; birds)
Rick Gustufson (CBD; fish)
Brad Hanson (CBD; whales)
Gretchen Hanshew (SFD; Fisheries Description)
Eli Holmes (CBD; pinnipeds)
Marla Holt (CBD; pinnipeds)
Isaac Kaplan (CBD; trophic analysis)
Janell Majewski (FRAMD; fishery description)
Sean Matson (SFD; Fisheries Description)
Eric Ward (CBD; whales)
Greg Williams (CBD; fish)
Pacific Fishery Management Council, Groundfish Management Team (Fisheries Description)

Ed Melvin and Troy Guy (Washington Sea Grant) made valuable contributions to the sea bird section; Alison Agness, Kevin Duffy, Frank Lockhart, Sheila Lynch, Becky Renko (NWR); Steve Lindley, Jay Barlow, Lisa Ballance, Jeffrey Seminoff (SWC); Dan Lawson, Lauren Saez (SWR) and Kim Rivera (AKR) all provided valuable review and input.

Table of Contents

Chapter 1: Introduction

The purpose of this report is to evaluate risks from the U.S. West Coast Groundfish Fisheries (WCGF) on a subset Endangered Species Act (ESA) listed marine species found off the West Coast (Table 1).

Table 1: List of ESA-listed species evaluated in this report

Marine Mammals
Blue whale (Balaenoptera musculus)
Fin whale (Balaenoptera physalus)
Humpback whale (Megaptera novaeangliae)
Sei whale (Balaenoptera borealis)
Sperm whale (Physeter macrocephalus)
Southern Resident killer whale DPS (Orcinus orca)
North Pacific Right whale (Eubalaena japonica)
Steller sea lion (Eumetopias jubatus), Eastern DPS
Guadalupe fur seal (Arctocephalus townsendi)
Sea Turtles
Leatherback turtle (Dermochelys coriacea)
Loggerhead turtle (Carretta Carretta)
Olive ridley (Lepidochelys olivacea)
Green turtle (Chelonia mydas)
Fish
Green sturgeon (Acipenser medirostris), Southern DPS
Eulachon (Thaleichthys pacificus), Southern DPS
Birds
Short-tailed albatross (Phoebastria albatrus)
California least tern (Sterna antillarum browni)
Marbled murrelet (Brachyramphus marmoratus)

The report is intended to assist the Pacific Fisheries Management Council (PFMC) and the National Marine Fisheries Service (NMFS) Northwest Regional Office with an evaluation of the WCGF under section 7 of the ESA. Section 7 of the ESA requires that federal agencies consult with NMFS on proposed actions that have the potential to harm listed species. Consultations are required for all federal fishery management plans, including the Pacific Coast Groundfish Fishery Management Plan (FMP). This report therefore summarizes the scientific information currently available to characterize the degree of risk imposed by the WCGF fishery on the species listed in Table 1.

Chapter 2: Description of the fisheries

Introduction

This section describes the federally managed Pacific Coast groundfish fisheries that may interact with Endangered Species Act (ESA) listed species and their critical habitat. The fishery description sets the context for assessing direct and indirect effects in later sections. Of primary concern here are those attributes that influence the exposure of listed species to the fishery and potential outcomes including:

- Gear Type and Target Species – Configuration of gear, including the potential for direct interaction with listed species and their critical habitat.
- Seasonality and Geographic Extent – When and where the gear is deployed for comparison with the distribution of listed species.
- Fishing Effort – The amount of fishing effort, particularly in areas of overlap with listed species.

Additional consideration is given to monitoring strategies, data sources, and management jurisdiction.

Overview of the Groundfish Fishery[2]

The West Coast Groundfish Fishery is diverse and includes over 90 different fish species in the Pacific Coast Groundfish Fishery Management Plan (FMP) that are caught by multiple commercial and recreational fisheries using many different gear types along the entire coast.

Managed species include the following:

- Rockfish – The plan covers 64 different species of rockfish, including widow, yellowtail, canary, shortbelly, vermilion, bocaccio, chilipepper, cowcod, yelloweye, thornyheads, and Pacific Ocean perch.
- Flatfish – The plan covers 12 species of flatfish, including various soles, starry flounder, arrowtooth flounder, and sanddab.
- Roundfish – The six species of roundfish included in the Fishery Management Plan are lingcod, cabezon, kelp greenling, Pacific cod, Pacific whiting (hake), and sablefish.
- Sharks and skates – The six species of sharks and skates are leopard shark, soupfin shark, spiny dogfish, big skate, California skate, and longnose skate.
- Other species – These include ratfish, finescale codling, and Pacific rattail grenadier.

---

[2] Adapted from PFMC 2011, pp. xiii-ix and West Coast Observer Program reports: http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/index.cfm

The National Marine Fisheries Service (NMFS) manages the fishery in partnership with the Pacific Fishery Management Council (PFMC), and the states of California, Oregon, and Washington. A major emphasis of the current fishery management framework is focused on rebuilding overfished species. A management framework is used that includes a variety of fixed elements and routine management measures that may be adjusted through a biennial harvest specifications process. The management measures are intended to constrain the total fishing mortality to within Annual Catch Limits (ACL). Additionally, they are designed to achieve other goals and objectives that pertain to socioeconomics and equitable utilization of the resource.

Regulations for the groundfish fishery are recommended by the PFMC and implemented by NMFS. Active management of the fishery began in the early 1980s with the establishment of optimum yields (OYs) for several managed species and trip limits for widow rockfish, the *Sebastes* complex, and sablefish. The objective of trip limits has been to slow the pace of landings to maintain year-round fishing, processing, and marketing opportunities. Since the 1980s, regulations have evolved to further separate individual groundfish species for management purposes and led to the current use of cumulative two-month trip limits and individual fishing quotas for most species (PFMC 2008). Cumulative trip limits are a specified weight of fish that can be landed during a particular time period.

Under the FMP, the groundfish fishery is defined as consisting of four management components:

- Limited Entry (LE) – The LE component includes all commercial fishers who hold a federal limited entry permit. The total number of limited entry permits available is capped, and permitted vessels are allotted a larger portion of the total allowable catch for commercially desirable species than non-permitted vessels.

- Open Access (OA) – The OA component includes commercial fishers who are not federally permitted. However, state agencies (California Department of Fish and Game and Oregon Department of Fish and Wildlife) have instituted permit programs for certain OA fisheries.

- Recreational – This component includes recreational anglers who target or catch groundfish species.

- Tribal – This component includes native tribal commercial fishers in Washington State that have treaty rights to fish groundfish.

These four components can then be further subdivided into sectors based on gear type, target species, and various regulatory factors. Commercial LE and OA sectors have traditionally caught the largest quantities of groundfish and are observed by federal at-sea observer programs.

Groundfish Fishery Sectors

Managers identify groundfish fishery sectors, around which regulations are structured. Commercial fisheries are identified based on the regulatory status, gear types, and target strategy of the vessels comprising each sector. From a regulatory standpoint, groundfish fisheries are identified based on whether vessels possess a federal groundfish limited access ("limited entry") permit and the particular endorsements on that permit. In addition, Washington coastal Indian Tribes prosecute groundfish fisheries based on treaty rights. Given their sovereign status, these fisheries are considered separately from other commercial fishery sectors.

An important reason for identifying fishery sectors relates to the allocation of catch opportunity. Overall catch limits by management unit (a stock, stock complex, or geographic subdivision of either) determined by the ACL may be divided among sectors for the purpose of management. These allocations may be "formal" or "informal." Formal allocations identified in the regulations and management measures are generally crafted in order to ensure that a sector has the opportunity to catch the portion of the ACL determined by an allocation. Informal or implicit allocations are a function of the particular management measures established as part of the biennial process for stocks that do not have a formal allocation. The way in which these management measures constrain catch opportunities creates functional allocations of the stocks available for harvest. In addition to allocations, managers also consider "set asides." These divisions of harvest opportunity play more of a bookkeeping function so that managers can estimate the total catch that is likely to occur during the management period. Set asides are an accounting device applied primarily to research catches and fisheries prosecuted under an exempted fishing permit (see below). Treaty fisheries are also accorded a set aside, because the sovereign status of these groups means that their fisheries are independently managed in coordination with the Council.

The following provides a list of sectors comprising the groundfish fishery and are further described later in the section. An analysis of anticipated changes is included at the end of this section. The following non-Tribal commercial fishery sectors are identified for the purposes of management:

1. Catcher-processor vessels targeting Pacific whiting using mid-water trawl gear and processing their catch at sea.
2. Catcher vessels targeting Pacific whiting using mid-water trawl gear and delivering to at-sea mothership processors (referred to as the mothership sector).
3. Catcher vessels targeting Pacific whiting using mid-water trawl gear and delivering to processing plants on land (referred to as the shoreside whiting sector).
4. Vessels using bottom trawl gear to target groundfish species other than Pacific whiting, with their catch landed onshore (referred to as the non-whiting trawl sector).
5. Vessels using longline or pot gear under gear switching provisions in the IFQ program.
6. Vessels using longline or pots (referred to as fixed gear) to target groundfish and possessing a federal limited entry permit with this gear endorsement (referred to as the limited entry fixed gear sector).
7. Vessels using legal groundfish gear other than trawl (principally longline and pot gear) to target groundfish but not possessing a federal limited entry permit (referred to as the "directed open access sector").

8. Incidental open access sector vessels using a variety of gear types that catch groundfish incidentally, usually defined by catch composition rather than regulatory status.

In addition to the above-mentioned sectors, a variety of fisheries are also considered in the groundfish management process as follows:

- The exempted trawl fisheries—pink shrimp, spot prawn, ridgeback prawn, and California halibut—incidentally catch groundfish. Vessels in this sector (often referred to as the "incidental open access sector,") are subject to the same trip limits and management measures imposed on the directed open access sector, and special measures may apply to particular fisheries, such as pink shrimp and California halibut trawl.
- Recreational groundfish fisheries, including charter vessels (commercial passenger fishing vessels [CPFVs]) and private recreational vessels (individuals fishing from their own or rented boats).
- Tribal fisheries are those fisheries prosecuted by Washington coastal tribes (Makah, Quileute, Hoh, and Quinault) in their usual and accustomed grounds and stations, under treaties with the Federal government.
- Exempted Fishing Permits (EFPs) are allocated groundfish harvest to authorize a vessel to engage in an activity that is otherwise prohibited by the MSA or other fishery regulations for the purpose of collecting limited experimental data.

Pacific Whiting

Pacific whiting form dense, semi-pelagic schools so that vessels targeting the species generally encounter only small amounts of bycatch. However, rockfish and salmon can be caught incidentally, either because they co-occur with Pacific whiting or because vessels mistakenly set the gear on the wrong species. The at-sea whiting sectors are managed through a season and quota structure. The season opens around May 1 each year (and occasionally a few weeks earlier off of central California). The third whiting sector, shore-based, is managed with individual fishing quota (IFQ). Pacific whiting is allocated among the three whiting sectors after a portion is set aside for expected catch in Tribal fisheries. The season for each sector then runs until its allocation is used up. As with other groundfish fisheries, catch limits on overfished rockfish have created a constraint on whiting fisheries, resulting in a "race for bycatch"—competition among the whiting sectors to catch their target species quota before limits on overfished species are reached. As a result, beginning with the 2009–2010 management period, sector-specific bycatch limits have been put in place for canary rockfish, darkblotched rockfish, and widow rockfish.

The Pacific whiting fisheries encompass the first three sectors described above; however, beginning in 2011, the shoreside whiting sector is combined with the non-whiting trawl sector and managed with Individual Fishing Quotas (IFQ). The mothership sector is managed through a co-op structure with catcher vessels within a co-op delivering to a specified mothership. The catcher-processor sector operates as a voluntary co-op. Prior to 2011, most vessels in the shoreside fishery operated under Exempted Fishing Permits (EFP, see below), where participants dumped unsorted catch directly into refrigerated tanks, rather than sorting the catch on deck. Individuals within this fishery may continue to maximize retention (i.e., dump all catch directly into refrigerated tanks) or sort their catch on deck, because 100% of IFQ Program trips are monitored by observers.

Commercial Limited Entry Bottom Trawl

The LE groundfish bottom trawl fishery off the west coast of the United States operates from the Canadian border to Morro Bay, California. In 2009, there were 178 LE trawl permits. Groundfish bottom trawl vessels range in size from 35 to 95 feet, with an average length of 65 feet. Vessels fish throughout the year in a wide range of depths and deliver catch to shoreside processors. Bottom trawlers often target species assemblages, which can result in diverse catch. A single groundfish bottom trawl tow often includes 15 to 20 species. It is expected that fleet size will be reduced considerably under the new IFQ Program (see below).

Commercial Limited Entry and Open Access Bottom Trawl – Targeting California Halibut

Vessels that participate in the California halibut trawl fishery can belong to either the LE or OA sector of the federal groundfish trawl fishery. Some vessels with a federal limited entry groundfish trawl permit also have a state California Halibut Bottom Trawl Vessel Permit, and these vessels primarily operate in federal waters out of the ports of Monterey and San Francisco. Federal LE groundfish-permitted vessels targeting California halibut are subject to federal groundfish regulations, depth-based conservation area closures, and trip limits for groundfish, and they must participate in a vessel monitoring system for enforcement purposes.

The California halibut trawl fishery generally operates out of U.S. ports from San Francisco to Los Angeles. Commercial bottom trawling is prohibited in California State waters, with the exception of the California Halibut Trawl Grounds (CHTG). The fishing season within the CHTG covers two calendar years. Regulations for vessels operating in the CHTG include minimum mesh sizes of 7.5 inches in length to reduce bycatch, a three-month closed season during California halibut spawning (March 15–June 15), a 500 pound possession limit on the incidental take of fish other than California halibut, a 22-inch minimum size limit for retained California halibut, and mandated federal observer coverage. A comprehensive review of the California halibut bottom trawl fishery in the CHTG was published by the California Department of Fish and Game (CDFG 2008). In federal waters, trawling for California halibut can occur year-round, but a state permit is required (as of 2006) to land more than 150 pounds of California halibut per trip.

Vessels range in size from 29 to 71 feet, with an average length of 46 feet. Fishing generally occurs in less than 30 fathoms of water, and fishers deliver their catch to shore-based processors.

Commercial Fixed Gear Sectors

There are four major sectors in the fixed gear groundfish fishery: the LE sablefish-endorsed sector, the LE non-sablefish-endorsed sector, the federal open access sector, and the state-permitted nearshore fisheries. There were 227 LE fixed gear permits in 2009. LE fixed gear permits are either sablefish-endorsed or non-sablefish-endorsed. In addition, all LE fixed gear permits have gear endorsements (longline, pot/trap, or both). Of the 227 LE fixed gear permits in 2009, 164 had sablefish-endorsements. Of these, 132 were associated with longline gear, 32 were associated with pot/trap gear, and 4 were associated with both longline and pot/trap gear. The remaining 63 limited entry non-sablefish-endorsed permits were all associated with longline gear. The open access fixed gear sector does not require federal or state permits. Therefore, the total number of participants varies widely from year to year. Open access vessels can use any type of hook-and-line or pot/trap gear, including longline, fishing pole, and vertical longline.

Limited Entry Sablefish Primary Tier-Endorsed Fixed Gear

Vessels participating in the LE sablefish-endorsed sector range in size from 33 to 95 feet and operate north of 36^{o} N. latitude. Fishing generally occurs in depths greater than 80 fathoms. Nearly all of the vessels participating in this sector deliver their iced catch to shoreside processors. Catch in the LE sablefish-endorsed fishery is composed mostly of sablefish, with bycatch primarily composed of spiny dogfish shark, Pacific halibut, rockfish species, and skates. LE sablefish-endorsed permits provide the permit holder with an annual share of the sablefish catch. Sablefish-endorsed permits are assigned to Tier 1, 2, or 3. Each Tier 1 permit receives 1.4% of the primary-season sablefish allocation, with Tiers 2 and 3 receiving 0.64% and 0.36%, respectively. Each year, these shares are translated into amounts of catch (in pounds), or "tier limits", which could be caught during the primary fishery. Regulations allow for up to three LE sablefish-endorsed permits to be 'stacked' on a single vessel. Permit stacking was implemented to increase the economic efficiency of the fleet and promote fleet capacity reduction. Stacking more than one sablefish-endorsed permit on a vessel allows the vessel to land sablefish up to the sum of the associated tier limits. However, permit stacking does not convey additive landing limits for any other species. LE sablefish-endorsed primary season fishing currently takes place over a seven-month period from April 1 to October 31. The seven-month season was first implemented in 2002. Permit holders land their tier limits at any time during the seven-month season. Once the primary season opens, all sablefish landed by a sablefish-endorsed permit is counted toward attainment of its tier limit. Vessels that have LE sablefish- endorsed permits can fish in the LE non-sablefish-endorsed fishery under trip limits once their quota of primary season sablefish has been caught or when the primary season is closed, from November 1 through March 31.

Limited Entry Non-Sablefish-Endorsed Fixed Gear

The LE non-sablefish-endorsed fixed gear sector occurs coastwide but operates primarily out of southern California ports. The fishery operates year-round, but the majority of fishing activity occurs during the summer months when weather conditions improve. Vessels in the LE non-sablefish-endorsed sector range in size from 17 to 60 feet, with an average length of 34 feet. Vessels catch a variety of groundfish species, including thornyheads, sablefish, rockfish, and flatfish. The fleet typically operates in depths greater than 80 fathoms. Nearly all of the vessels participating in this fishery deliver their iced catch to fresh fish markets. LE non-sablefish-endorsed fixed gear permits are subject to daily and weekly trip limits for sablefish, thornyheads, and other groundfish species.

Open Access Fixed Gear

As the open access sector of the fixed gear groundfish fishery does not require federal or state permits (state requirements for commercial fishing licenses notwithstanding), characterizing the participants can be difficult. Vessels range in size from 10 to 97 feet, with an average length of 33 feet. Vessels catch a variety of groundfish species, including sablefish, spiny dogfish, and skates. Vessels operate out of all three coastal states and generally fish in waters shoreward of 30 fathoms or seaward of 100 fathoms. Open access fixed gear vessels are subject to daily and weekly trip limits for sablefish, spiny dogfish shark, and other groundfish species. Flatfish species—including dover sole, arrowtooth flounder, petrale sole, English sole, starry flounder, and all other flatfish—are managed as a single group for the open access fishery.

State-Permitted Nearshore Fixed Gear

The state-permitted nearshore groundfish sectors operate from northern Oregon to southern California. Vessels that participate in the state-permitted nearshore fixed gear fisheries can belong to either the federal limited entry or open acces fixed gear sectors. Historically, nearshore fisheries were accessible to everyone. However, due to the increasing number of participants and concerns of overcapacity, California and Oregon began requiring state permits in 2003 and 2004, respectively. Regulations for the nearshore fisheries are set by both the PFMC and the states. The PFMC sets the ACL for groundfish species and harvest guidelines.

In addition to regulations set by the PFMC, each state manages its nearshore fishery independently by issuing state regulations on the cumulative trip limits of nearshore species in their state waters. Cumulative trip limits are a specified weight of fish that can be landed during a particular time period, usually two-months. Often, cumulative trip limits set by the states are more restrictive than the federal limits. Additional management measures for each state are highlighted in the sections below. Further information on state nearshore fishery regulations can also be found online for Oregon at: (http://www.dfw.state.or.us/mrp/regulations/commercial_fishing/index.asp) and for California at: (www.dfg.ca.gov/marine/regulations.asp#commercial).

Vessels participating in the nearshore fisheries range in size from 10 to 50 feet, with an average length of 25 feet. They use a variety of fixed gear, including hand-lines, cable gear, fishing poles, longlines, and pots. In shallow water, fishers often fish in coves or drift along a reef. They set and retrieve their gear multiple times a day and generally land their fish on a daily basis. Quotas for the nearshore fisheries are small—generally between 100 to 2,000 pounds every two-months although can be higher for some species. Many of those who fish in shallow water participate in the live fish market, necessitating careful handling of retained fish.

Washington

The State of Washington does not allow commercial fishing within its territorial waters (0–3 miles from the coastline). This prohibition removes fishing grounds from access by commercial nearshore fishers.

Oregon

Oregon's nearshore commercial fishery typically occurs in shallow water (< 30 fathoms) and targets species, such as black rockfish, blue rockfish, china rockfish, copper rockfish, quillback rockfish, grass rockfish, cabezon, and greenlings. Oregon's nearshore permitting process assigns permits to vessels. State nearshore management employs minimum size limits for many nearshore species, as well as two-month cumulative trip limits and annual landing caps (maximum landed weight in a 12-month period), and annual harvest caps that include all sources of fisheries-mortality. Black rockfish trip limits are tied to four latitudinal Oregon Black Rockfish Zones. In 2004, Oregon began requiring that nearshore fishers complete a vessel logbook.

In 2009, Oregon issued 55 black/blue rockfish permits, which allow for the landing of black rockfish and blue rockfish, and 72 black/blue rockfish permits with a nearshore endorsement, which allows landing of black rockfish and blue rockfish along with 21 additional Oregon designated nearshore groundfish species. In 2010, Oregon issued 55 black/blue rockfish permits and 70 black/blue rockfish permits with a nearshore endorsement.

California

California state management designates four geographic zones along the coastline. State management has implemented seasonal closures in some south of 40°10'N latitude. The north coast area (north of 40°10'N latitude to the Oregon-California border) remained open year-round, except for seasonal closures of cabezon, greenlings, and California sheephead.

The State of California issues two permits for fishing within the nearshore area: (1) a shallow nearshore species fishery permit, and (2) a deeper nearshore species fishery permit. In 2009, there were a total of 319 California nearshore permits, and in 2010, there were 304 permits. The permits are assigned to an individual person and can only be used in the one regional management area specified on the permit. Fishers can either have a single nearshore permit (deeper or shallow) or hold both types of permits. A trap endorsement can also be tied to a shallow nearshore permit to allow for the use of trap gear when fishing for nearshore species. In addition, a nearshore fishery bycatch permit can be issued for trawl gear or entangling nets to allow for small amounts of nearshore landings per trip, but only in two management zones.

The deeper nearshore permit is required for landing black rockfish, blue rockfish, brown rockfish, calico rockfish, copper rockfish, olive rockfish, quillback rockfish, and treefish. The shallow nearshore permit is required for landing black-and-yellow rockfish, cabezon, California scorpionfish, California sheephead, china rockfish, gopher rockfish, grass rockfish, greenlings, and kelp rockfish. Lingcod is also commonly targeted in conjunction with shallow nearshore permit species. Most live fish landings consist of species in the shallow nearshore group. State nearshore management employs minimum size limits for many nearshore species and two-month cumulative trip limits. A limit on the number of hooks per vessel or line also exists for certain areas. California instituted a voluntary nearshore logbook program in 2005.

Recreational Fisheries

Recreational fisheries are primarily managed by the states, so catch and effort data are often grouped by state and sub-state region. A distinction is also made between charter vessels (commercial passenger fishing vessels, or CPFVs) and private recreational vessels (individuals fishing from their own or rented boats). As would be expected, participation is higher during warmer months. The number of marine angler trips peaks in the July–August period, but the seasonal concentration is more pronounced in northern areas. For example, in 2003, Washington

State saw no trips recorded in November–December, and 36% of trips were in July–August, while in Southern California the proportions for the same periods were 12% and 30%, respectively (PFMC 2011).

Tribal Groundfish Fisheries

West Coast treaty tribes have formal allocations or set-asides for sablefish, black rockfish, and Pacific whiting. The tribes also have harvest guidelines for Pacific cod and lingcod. Members of the four coastal treaty tribes participate in commercial, ceremonial, and subsistence fisheries for groundfish off the Washington coast. Participants in the tribal commercial fisheries use similar gear to non-tribal fishers. Groundfish caught in the tribal commercial fishery pass through the same markets as non-tribal commercial groundfish catch.

There are several groundfish species taken in tribal fisheries for which the tribes have no formal allocations and some species for which no specific allocation has been determined. Rather than try to reserve specific allocations of these species, the tribes recommend trip limits for these species to the Council, which then managed other sectors to accommodate these fisheries. Tribal trip limits for groundfish species without tribal allocations are usually intended to constrain direct catch as well as interactions of overfished species in the tribal groundfish fisheries.

Thirteen western Washington tribes possess and exercise treaty fishing rights to halibut, including the four tribes that possess treaty fishing rights to groundfish. Tribal halibut allocations are divided into a tribal commercial component and the year-round ceremonial and subsistence component.

Approximately one-third of the tribal sablefish allocation is taken during an open competition fishery, in which vessels from the sablefish tribes all have access to this portion of the overall tribal sablefish allocation. The open competition portion of the allocation tends to be taken during the same period as the major tribal commercial halibut fisheries in March and April. The remaining two-thirds of the tribal sablefish allocation is split among the tribes according to a mutually agreed-upon allocation scheme. Specific sablefish allocations are managed by the individual tribes, beginning in March and lasting into the autumn, depending on vessel participation and management measures used. Participants in the halibut and sablefish fisheries tend to use hook-and-line gear, as required by the International Pacific Halibut Commission (IPHC). By agreement the tribes also use snap gear for equity reasons in the fully competitive sablefish fishery (i.e., someone participating in a fully competitive sablefish fishery who landed no halibut would not have to meet any IPHC requirements, but would still have to use snap line gear by tribal regulation).

In addition to these hook-and-line fisheries, the Makah tribe annually harvests a whiting allocation using midwater trawl gear. Since 1996, a portion of the U.S. whiting OY has been allocated to the Pacific Coast treaty tribes {50 CFR 660.385(e)}. The tribal allocation is subtracted from the whiting OY before allocation to the non-tribal sectors. From 1999 to 2009, the tribal allocation was based on a sliding scale related to the U.S. whiting OY. Since 2009, the tribal allocation has been based on estimated need by tribes anticipating participating in the fishery. To date, only the Makah tribe has conducted a whiting fishery.

Makah non-whiting vessels fit with mid-water trawl gear have also been targeting yellowtail rockfish in recent years. Tribal regulations specify the monthly limit of yellowtail, based on the number of vessels participating, as well as limits for canary rockfish (300 pounds per trip), and minor nearshore, shelf, and slope rockfish (300 pounds per trip combined) and interactions with widow rockfish (not to exceed 10% of yellowtail landings). This fishery is managed by both time and area to stay within projected impacts on overfished rockfish, primarily widow and canary, taken incidentally with yellowtail. Short test tows are taken in areas previously identified as having low bycatch rates before that area is open to fishing. If vessels in the fishery approach the limits established by tribal regulation, the area is closed to further fishing until it can be shown to have reduced bycatch rates. An observer program is in place to verify bycatch levels in the fishery, and assigned vessels must carry an observer to participate.

Table 2: Distribution of vessels engaged in Tribal groundfish fisheries (Source PFMC 2011).

Treaty Tribe	Number of Vessels in Groundfish Fishery				Port
	Longline (length in ft)	Whiting (length in ft)	Trawl (length in ft)	Total	
Makah	31 (33'-62')	5 (95'-124')	5 (49'-62')	45	Neah Bay
Hoh	-	-	-	1	N/A
Quileute	8 (45’-68’)	-	-	8	La Push
Quinault	15(38'-62')	-	-	15	West Port

Exempted Fishing Permits

An Exempted Fishing Permit (EFP) is a NMFS-issued federal permit that authorizes a vessel to engage in an activity that is otherwise prohibited by the MSA or other fishery regulations for the purpose of collecting limited experimental data. EFPs can be issued to federal or state agencies, marine fish commissions, or other entities, including individuals.

The specific objectives of a proposed exempted fishery may vary. The Groundfish FMP provides for EFPs to promote increased utilization of underutilized species, realize the expansion potential of the domestic groundfish fishery, and increase the harvest efficiency of the fishery consistent with the MSA and the management goals of the FMP. However, EFPs are commonly used to explore ways to reduce effort on depressed stocks, encourage innovation and efficiency in the fisheries, provide access to constrained stocks while directly measuring the bycatch associated with those fishing strategies, and evaluate current and proposed management measures. EFPs are adopted biennially with preliminary adoption by the Council at their November meeting and final approval in June. For additional information on EFP protocols, visit the Council website and review Council Operating Procedure 19 at: (www.pcouncil.org/operations/cops.html).

Seasonality

Groundfish are commercially harvested year-round with changes in effort related to management and markets. Seasonality of the groundfish fisheries varies by sector and is shown in Table 3. As described above, the seasonality of Pacific whiting fisheries is driven by regulations which open the season around May 1 each year (and occasionally a few weeks earlier off of central California). The season for each Pacific whiting sector then runs until its allocation is used up.

Table 3: Seasonality of non-whiting commercial groundfish landings—over 2005–2009 timeframe, average in metric tons per two-month seasons by sector (excerpted from PFMC 2011, p. F-14)

Sector	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
Shoreside Non-whiting Trawl	3,637.56	3,672.64	3,918.75	3,988.75	3,788.83	2,659.96
Limited Entry Fixed Gear	101.90	261.88	678.20	759.48	718.41	119.06
Open Access Fixed Gear	101.82	142.69	266.89	280.65	289.08	187.65
Incidentally Caught	25.58	23.40	37.23	48.43	37.08	10.70
Tribal Shoreside Nonwhiting Groundfish	68.71	427.75	362.38	304.72	299.57	172.77

Recreational effort tends to peak during warmer months, particularly in Oregon and Washington where weather is more variable. Figure 1 shows the seasonal distribution of recreational fishing activity off the West Coast.

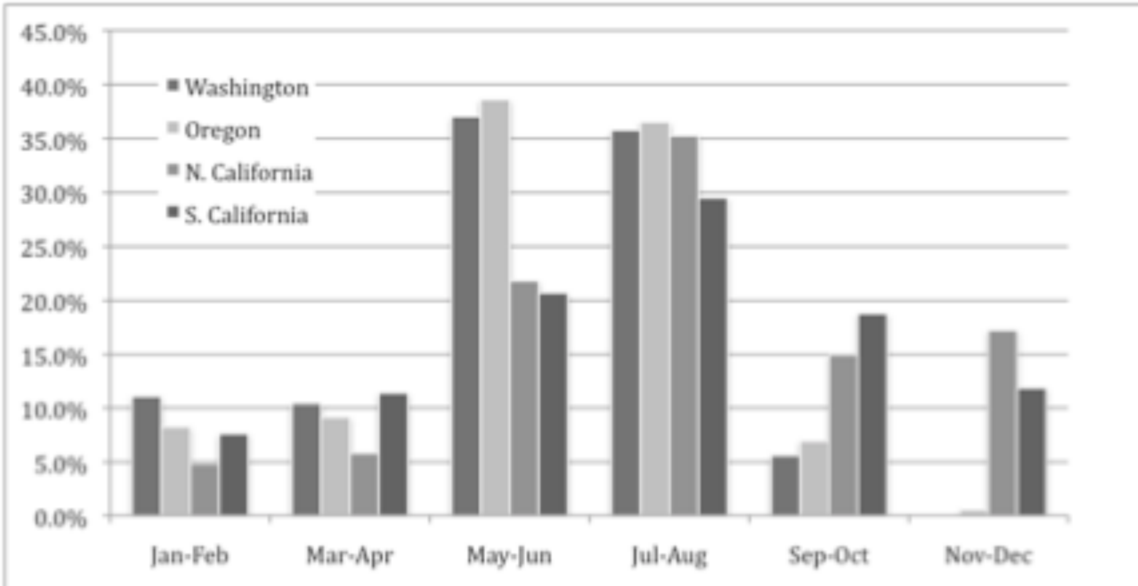


Figure 1: Seasonal distribution of marine angler trips in 2003 (Source PFMC 2011).

Geographic Extent

Groundfish are harvested coastwide in state and federal waters. The fishery is constrained in some cases by established Marine Protected Areas, such as those to protect groundfish Essential Fish Habitat (EFH) (PFMC 2005). In other cases, area closures are implemented through the harvest specification process to protect overfished species (PFMC 2011). Table 4 shows groundfish landings by port group during 2009 (excerpted from PFMC 2011, p. F-24). Figure 2 shows several maps of commercial fishing effort for West Coast groundfish fisheries.

Table 4: Commercial groundfish landings (mt) by sector and port group for 2009 (x=excluded for data confidentiality) (excerpted from PFMC 2011, p. F-24).

Port Group	Shoreside Whiting Trawl	Shoreside Nonwhiting Trawl	Limited Entry Fixed Gear	Open Access Fixed Gear	Incidentally Caught Groundfish	Total
Puget Sound		1,295.5	257.4		x	x
North Washington Coast		x	220.2	23.1	1.7	x
South & Central Washington Coast	10,090.9	1,346.2	308.6	41.0	3.8	11,790.6
Astoria	14,085.8	8,406.4	148.3	16.5	5.1	22,662.2
Tillamook		x		34.5	0.2	x

Newport	12,993.0	3,774.6	525.1	42.4	11.8	17,347.0
Coos Bay	x	3,619.1	191.4	85.2	6.5	x
Brookings		1,201.1	263.5	276.9	1.8	1,743.3
Crescent City	1,489.4	982.5	108.0	81.4	0.4	2,661.7
Eureka	x	2,678.7	101.8	73.0	x	3,162.0
Fort Bragg		1,684.1	154.6	102.9	0.6	1,942.3
Bodega Bay		x	x	17.2	3.8	81.4
San Francisco		648.5	59.9	36.3	29.0	773.7
Monterey		x	108.2	72.3	0.7	x
Morro Bay		x	202.0	568.8	2.1	x
Santa Barbara			35.6	74.2	15.9	125.7
Los Angeles			117.7	12.9	12.7	143.2
San Diego			82.1	13.3	3.8	99.2
Total	40,580.1	26,164.7	x	1,571.1	104.7	71,314.5

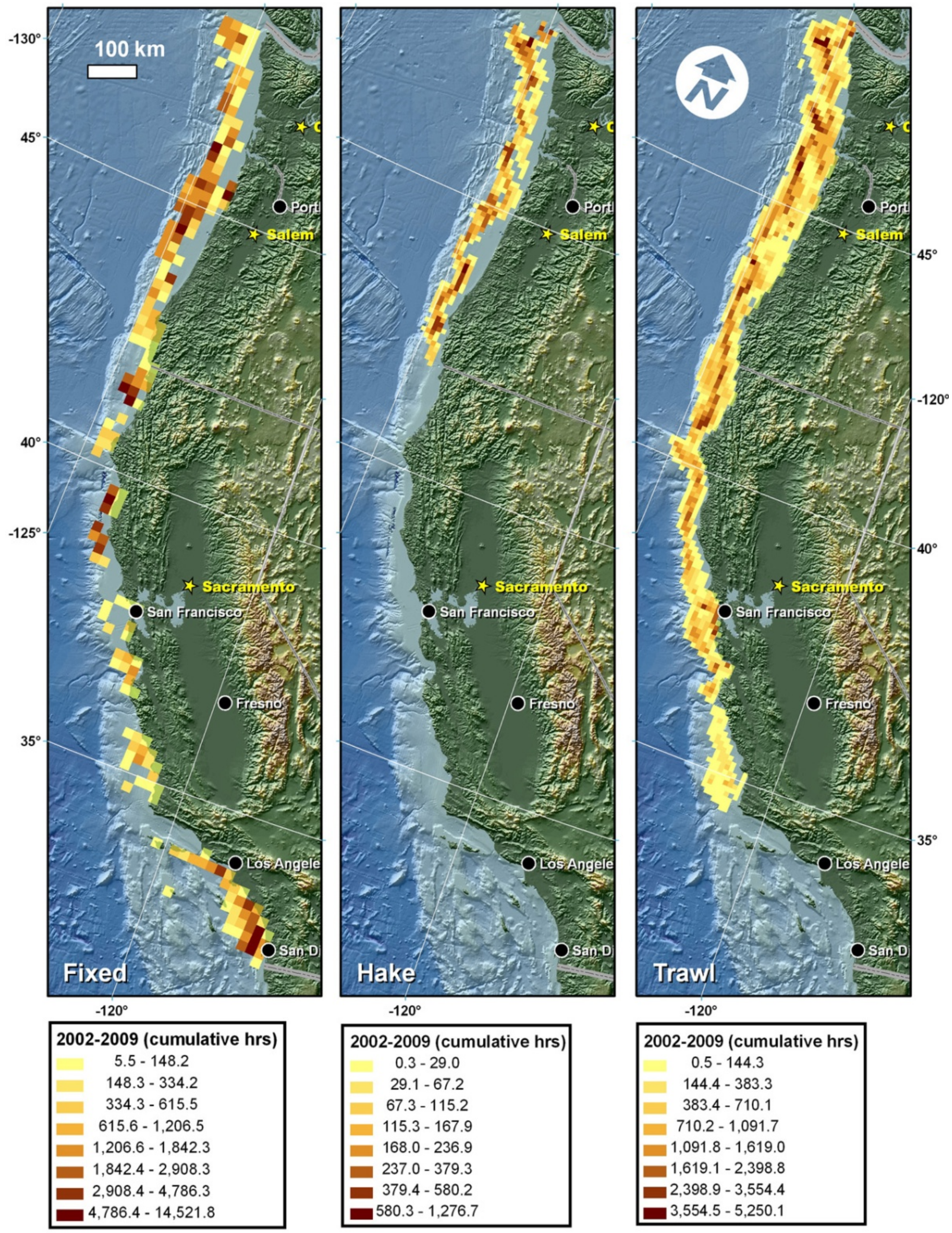


Figure 2: The figure demonstrates the general spatial distribution of fishing effort from 2002–2009 (as cumulative hours gear was deployed) in various sectors of the groundfish fishery for which spatial fishing effort information is available. Fixed represents the limited entry sablefish primary, limited entry non-sablefish endorsed, open access fixed gear, and state-permitted nearshore fixed gear sectors. Hake represents all at-sea hake sectors. Trawl represents the limited entry bottom trawl sector.

Gear Fished in the Groundfish Fishery

Many different types of fishing gear are used in West Coast fisheries and specifically in commercial, tribal, and recreational fisheries. Gear types include trawl nets, gillnets, longline, troll, jig, rod and reel, vertical hook and line, pots (also called traps), and other gear (e.g., spears, throw nets). Technical descriptions of each type of gear used on the West Coast (groundfish and non-groundfish fisheries) are available in the West Coast Observer Program Training Manual (NWFSC 2011) and are incorporated by reference. Table 5 summarizes the gear types used in West Coast fisheries.

Longline fisheries involve setting out a horizontal line, to which other lines (gangions) with baited hooks are attached. This horizontal line is secured between anchored lines and identified by floating surface buoys, bamboo poles, and flags. The longline may be laid along or just above the ocean floor (a bottom longline) or may be fished in the water column (floating or pelagic longline). Figure 3 shows typical bottom longline gear deployed in the groundfish fishery.

Trawling involves the towing of a funnel shaped net or nets behind a fishing vessel. The trawl gear varies depending on the species sought and the size and horsepower of the boats used. Trawl gear may be fished on the bottom, near the bottom, or up in the water column to catch a large variety of species. Figure 4 shows trawl gear as it is generally deployed on the West Coast.

Table 5: Gear Types Used in West Coast Fisheries (Source PFMC 2005).

	Nets	**Longline, Pot, Hook and Line Gears**	**Other Gears**
Limited Entry	Bottom Trawl Mid-water Trawl Scottish Seine	Pot Longline Vertical hook/line Rod and reel Troll/dinglebar Jig Stick Gear	
Open Access – Directed	Set Gillnet Sculpin Trawl	Pot Longline Vertical hook/line Rod and reel Troll/dinglebar Jig Stick Gear	
Open Access – Incidental	Exempted Trawl (pink shrimp, spot and ridgeback prawn, Calif. halibut, sea cucumber) Setnet Driftnet Purse seine	Pot (Dungeness crab, sheephead, spot prawn) Longline Rod and reel Troll	Dive/spear Dive/hook and line Poke pole
Tribal	As above	As above	As above
Recreational	Dip net	Hook and Line	Dive/spear

	Throw net	Pots	

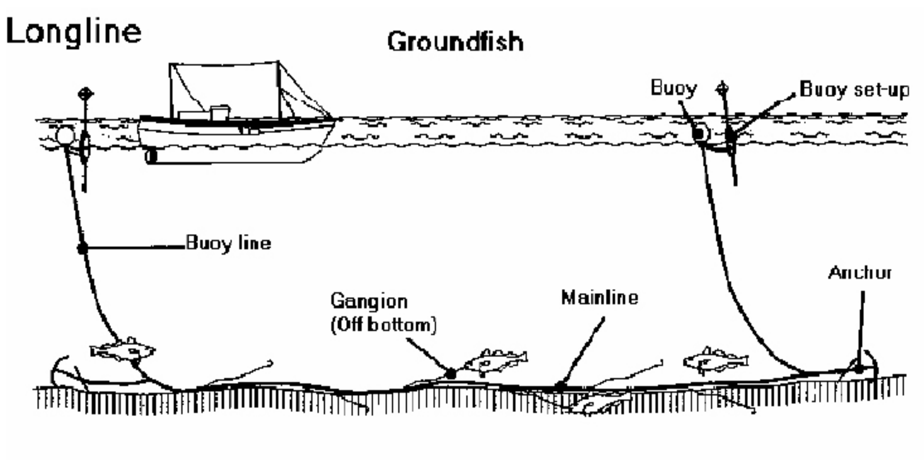


Figure 3: Schematic of groundfish longline gear (source NWFSC 2011).

To reduce take of seabirds, streamer lines (also called bird lines or tori lines) are sometimes deployed as the gear is set in the water (see Figure 5). A streamer line is a 50-fathom (or 90-meter) line that extends from a high point near the stern of the vessel to a drogue (usually a buoy with a weight). As the vessel moves forward, the drogue creates tension in the line, producing a span from the stern where the streamer line is aloft. The aloft section includes streamers made of UV-protected, brightly colored tubing spaced every 16 feet (5 meters). Streamers must be heavy enough to maintain a near-vertical fence in moderate to high winds. Individual streamers should extend to the water to prevent aggressive birds from getting to the groundline. When deployed in pairs—one from each side of the stern—streamer lines create a moving fence around the sinking groundline eliminating birds (Melvin 2000). Streamer lines have been effective at reducing seabird bycatch in Alaskan fisheries (USFWS 2008; Ed Melvin, personal communication; and, http://www.afsc.noaa.gov/Quarterly/amj2011/divrptsREFM4.htm). Seabird mitigation is not currently required in West Coast groundfish fisheries, although Washington Sea Grant has recently initiated a NMFS-funded program to promote voluntary use of streamer lines (WA Sea Grant 2011).

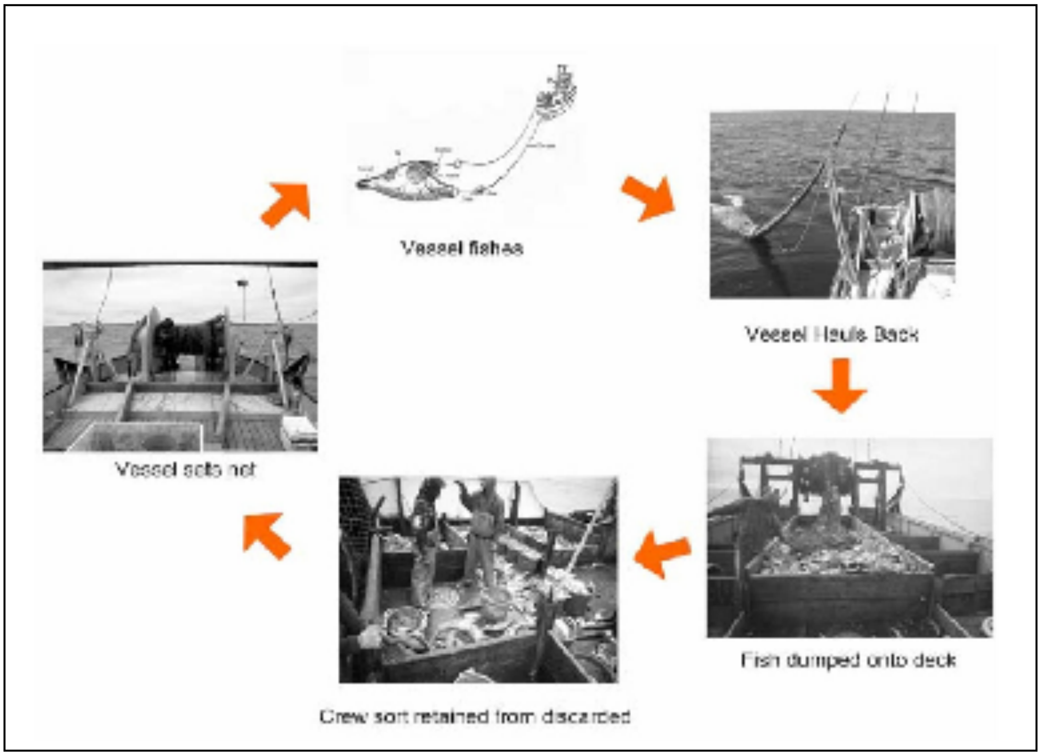


Figure 4: Typical activity on a groundfish trawl vessel (source NWFSC 2011).

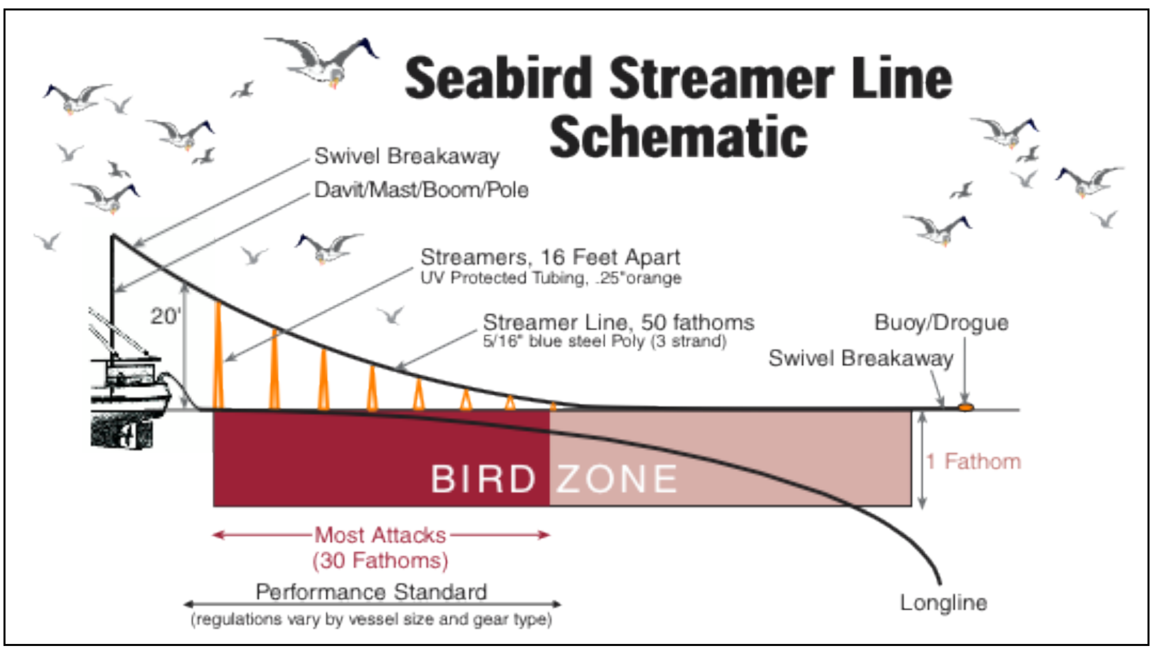


Figure 5: Schematic of streamer lines to reduce seabird bycatch (modified from Melvin 2000).

Catch Monitoring, Accounting, and Enforcement[3]

Establishing a standardized bycatch reporting methodology and limiting bycatch to the extent practicable are mandates of the Magnuson-Stevens Fishery Conservation and Management Act, referred to as the Magnuson-Stevens Act (MSA).[4] Effective bycatch accounting and control mechanisms are also critical for staying within ACLs. The first element in limiting bycatch is accurately measuring bycatch rates by time, area, depth, gear type, and fishing strategy.

At its November 2005 meeting, the Council approved Amendment 18 to the Groundfish FMP. The Council recommendation addresses National Standard 9 and Section 303(a)(11) of the MSA, which require practicable means to minimize bycatch and bycatch mortality and a standardized bycatch reporting methodology. The purpose of FMP Amendment 18 is to clearly and comprehensively describe measures that address these requirements, which have been established through long-term regulations and the biennial management process. The amendment also describes new measures that could be implemented by future regulatory or amendment actions. For additional information on Amendment 18, see the Council web page at: (www.pcouncil.org/groundfish/gffmp/gfa18.html).

Various state, federal, and tribal catch monitoring systems are used in West Coast groundfish management. There are two components to total catch: (1) catch landed in port, and (2) catch discarded at-sea. A description of the relevant data systems used to monitor total catch and discards in commercial and recreational groundfish sectors follows.

Data Collection Programs – Commercial sectors

Monitoring Commercial Landings

Sorting requirements monitoring programs are in place for all groundfish species and species groups with IFQ, trip limits, harvest guidelines, or ACLs including all overfished species. This provides accounting for the weight of landed depleted species when catches are hailed at-sea or landed. Limited entry groundfish trawl fishermen are also required to maintain state logbooks to record the start and haul locations, time, duration of trawl tows, and the total catch by species market category (i.e., those species and complexes with sorting requirements). Landings are recorded on state fish receiving tickets. Fishtickets are designed by the individual states, PSMFC coordinates record-keeping requirements between state and federal managers. Poundage by sorted species category, area of catch, vessel identification number, and other data elements are required on fishtickets. Landings are also sampled in port by state personnel to collect species composition data, otoliths for ageing, lengths, and other biological data. A suspension of at-sea sorting requirements coupled with full retention of catch is allowed in the whiting fishery (by FMP Amendment 10 and an annual EFP in the Shoreside Whiting sector). Fishticket landings, logbook data, and state port sampling data are reported as the season

[3] This Section Excerpted from Chapter 4 of PFMC 2008 with minor adaptations.
[4] For more information on bycatch, including NMFS' definition of bycatch, see: http://www.nmfs.noaa.gov/by_catch/SPO_final_rev_12204.pdf

progresses to the regional commercial catch monitoring database and the Pacific Fisheries Information Network (PacFIN), managed by PSMFC (www.psmfc.org/pacfin/index.html).

The Groundfish Management Team (GMT - advisory body to the PFMC) and PSMFC manage the Quota Species Monitoring (QSM) dataset reported in PacFIN for the purpose of informing inseason managment. All landings of groundfish stocks of concern (e.g., overfished stocks) and target stocks and stock complexes in West Coast fisheries are tracked in QSM reports of landed catch. The GMT recommends prescribed landing limits and other inseason management measures to the Council to attain, but not exceed, total catch ACLs of QSM species. Stock and complex landing limits are modified inseason to control total fishing-related mortality; QSM reports and landed catch forecasts are used to control the landed catch component.

At-Sea Hake Observer Program

There are two federal observer programs that collect information aboard groundfish vessels on the U.S. West Coast. These are separate programs because they deal with distinctly different components of the groundfish fishery: the federally permitted sectors targeting Pacific hake using mid-water trawl gear which processes catch at-sea, and the federal and state permitted sectors targeting non-hake species that deliver shoreside.

Observers were first deployed in the at-sea hake sectors in the late 1970s under the management of the North Pacific Groundfish Observer Program at NOAA's Alaska Fishery Science Center. NMFS made observer coverage mandatory for at-sea processors in July 2004 (65 FR 31751). The At-Sea Hake Observer Program (A-SHOP), now at NOAA's Northwest Fisheries Science Center (NWFSC), places fishery observers on all vessels that process Pacific hake at-sea. The at-sea hake sector consists of 8 to 14 catcher-processor vessels and motherships, along with the associated catcher vessels, that begin fishing in mid-May of each year and continue until the hake quota is reached or until bycatch caps are met. 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. As of January 2011, all catcher vessels delivering to at-sea processor/vessels require 100% observer coverage as well. At-sea hake observers monitor and record catch data in accordance with protocols detailed in the A-SHOP manual available online at: http://www.nwfsc.noaa.gov/research/divisions/fram/observer/observer_manuals.cfm.

To increase the utilization of bycatch otherwise discarded as a result of trip limits, Amendment 13 to the Groundfish FMP implemented an increased utilization program on 1 June 2001, which allows catcher/processors and motherships in the whiting fishery to exceed groundfish trip limits without penalty, providing specific conditions are met. These conditions include provisions for 100% observer coverage, non-retention of prohibited species, and either donation of retained catch in excess of cumulative trip limits to a bona fide hunger relief agency or processing of retained catch into mince, meal, or oil products.

West Coast Groundfish Observer Program

Non-hake groundfish sectors are observed by the West Coast Groundfish Observer Program (WCGOP), which was established in May 2001 by NOAA Fisheries (NMFS) in accordance with the Pacific Fishery Management Plan (50 CFR Part 660) (50 FR 20609). This regulation requires that all vessels that catch groundfish in the U.S. Exclusive Economic Zone (EEZ) from 3–200 miles offshore carry an observer when notified to do so by NMFS or its designated agent. Subsequent state rule-making has extended NMFS's ability to require that vessels, which only fish in the 0–3 mile state territorial zone, also carry observers. WCGOP observers are stationed along the U.S. West Coast from Bellingham, Washington to San Diego, California.

The WCGOP's goal is to improve estimates of total catch and discard by observing shoreside groundfish sectors along the U.S. West Coast. Originally, the WCGOP focused observer effort in the LE bottom trawl and LE fixed gear sectors. Obsesrver coverage has varied considerably among sectors (Table 6 -- Table 9). In 2002, the WCGOP began deploying observers in open access sectors while increasing its coverage of the LE bottom trawl sector. In 2005, the WCGOP increased its coverage of the LE fixed gear sector, and in 2006, the WCGOP improved coverage of the nearshore sector. Observer coverage in the open access fixed gear sector has generally been very low (Table 9). In 2010, the WCGOP coverage goal was to maintain, at a minimum, 20% coverage in the LE bottom trawl and LE fixed gear sectors by landings, while continuing to improve coverage in the open access sectors of the groundfish fishery. In 2011, WCGOP coverage of the LE bottom trawl sector increased to 100% under the catch share management structure with IFQs. An observer coverage plan from the WCGOP is available at:
(http://www.nwfsc.noaa.gov/research/divisions/fram/observer/observer_manuals.cfm).

Additionally, the NWFSC has worked closely with the Council and NMFS Northwest Region (NWR) to coordinate the availability of WCGOP results into the management regime. The WCGOP has released annual reports since 2003 that describe the analysis of observer data for various fishery sectors and species collected under the program. These reports and background materials on the WCGOP are available on the Northwest Fisheries Science Center website at:
(http://www.nwfsc.noaa.gov/research/divisions/fram/observer/observer_manuals.cfm).

Table 6 -- Total trips, tows, vessels and groundfish landings observed in the limited entry groundfish bottom trawl fishery. Coverage rates are computed as the observed proportion of total FMP groundfish landings (excluding Pacific hake), summarized from fish ticket landing receipts. See **http://www.nwfsc.noaa.gov/research/divisions/fram/observer/sector_products.cfm#coverage-rates** for more detailed information.

Coastwide Total						
	Observed				Fleet Total	Coverage Rate
Year	# of trips	# of tows	# of vessels	Groundfish landings (mt)	Groundfish landings (mt)	% landings observed
2002	559	3127	131	2583.7	20231.6	13%
2003	461	2284	125	2592.0	18625.6	14%
2004	613	3433	103	4300.7	17796.8	24%
2005	522	3460	105	4243.2	19372.6	22%
2006	476	2972	87	3438.4	17876.8	19%
2007	371	2515	88	3442.1	20513.6	17%

2008	438	3185	100	4889.6	24212.4	20%
2009	588	4381	101	6044.9	26159.5	23%
2010	348	2616	84	4100.3	22410.2	18%

Table 7 -- Total trips, tows, vessels and sablefish and groundfish landings observed in the limited entry sablefish-endorsed fixed gear groundfish fishery during the primary season. Coverage rates are computed as the observed proportion of total sablefish or groundfish landings, summarized from fish ticket landing receipts. See **http://www.nwfsc.noaa.gov/research/divisions/fram/observer/sector_products.cfm#coverage-rates** for more detailed information.

	Coastwide Total								
	Observed					Fleet Total		Coverage Rate	
Year	# of trips	# of tows	# of vessels	Sablefish landings (mt)	Groundfish landings (mt)	Sablefish landings (mt)	Groundfish landings (mt)	% Sablefish landings observed	% Groundfish landings observed
2002	91	638	31	273.3	298.6	1064.4	1287.0	26%	23%
2003	82	711	20	371.2	390.1	1504.7	1639.6	25%	24%
2004	58	459	19	261.8	272.0	1830.5	1919.6	14%	14%
2005	139	1154	32	762.6	813.9	1757.2	1889.2	43%	43%
2006	106	757	24	496.8	519.9	1855.9	1992.0	27%	26%
2007	105	671	26	388.6	461.4	1406.6	1563.5	28%	30%
2008	101	868	24	574.9	599.9	1343.9	1478.6	43%	41%
2009	73	354	12	164.7	177.2	1843.3	1986.6	9%	9%
2010	180	1068	27	511.2	541.6	1792.3	1929.9	29%	28%

Table 8 -- Total trips, tows, vessels and sablefish and groundfish landings observed in the limited entry non-sablefish-endorsed fixed gear groundfish fishery. Coverage rates are computed as the observed proportion of total sablefish or groundfish landings, summarized from fish ticket landing receipts. See **http://www.nwfsc.noaa.gov/research/divisions/fram/observer/sector_products.cfm#coverage-rates** for more detailed information.

	Coastwide Total								
	Observed					Fleet Total		Coverage Rate	
Year	# of trips	# of tows	# of vessels	Sablefish landings (mt)	Groundfish landings (mt)	Sablefish landings (mt)	Groundfish landings (mt)	% Sablefish landings observed	% Groundfish landings observed
2002	11	22	4	1.7	3.0	142.4	275.5	1%	1%
2003	130	219	17	14.3	32.1	135.7	309.2	11%	10%
2004	62	130	14	3.7	15.9	109.4	283.2	3%	6%
2005	35	60	11	2.4	9.3	134.3	306.7	2%	3%
2006	121	196	21	6.9	23.7	123.1	306.0	6%	8%
2007	158	303	36	16.5	37.5	113.1	260.2	15%	14%

2008	122	220	32	9.3	31.7	136.5	292.4	7%	11%
2009	138	271	34	12.0	30.3	279.9	444.8	4%	7%
2010	226	470	38	33.8	57.3	359.4	613.4	9%	9%

Table 9 -- Total trips, tows, vessels and sablefish and groundfish landings observed in the open access fixed gear groundfish fishery. Coverage rates are computed as the observed proportion of total sablefish or groundfish landings, summarized from fish ticket landing receipts. See **http://www.nwfsc.noaa.gov/research/divisions/fram/observer/sector_products.cfm#coverage-rates** for more detailed information.

	Coastwide Total								
	Observed					Fleet Total		Coverage Rate	
Year	# of trips	# of tows	# of vessels	Sablefish landings (mt)	Groundfish landings (mt)	Sablefish landings (mt)	Groundfish landings (mt)	% Sablefish landings observed	% Groundfish landings observed
2002						358.5	433.0	0%	0%
2003	57	99	20	10.0	19.5	517.5	647.9	2%	3%
2004	136	235	30	24.3	33.2	419.7	562.1	6%	6%
2005	77	87	24	17.1	20.5	855.7	919.5	2%	2%
2006	48	50	22	10.6	12.4	736.9	825.4	1%	2%
2007	95	138	44	18.5	19.1	417.8	442.2	4%	4%
2008	111	141	51	23.0	26.6	517.1	570.3	4%	5%
2009	93	146	48	25.7	30.2	921.3	983.7	3%	3%
2010	105	173	60	30.0	33.7	990.3	1092.0	3%	3%

Shore-based Pacific Whiting Observation Program

The Shoreside Hake Observation Program (SHOP) was established in 1992 to provide information for evaluating bycatch in the directed Pacific whiting fishery and for evaluating conservation measures adopted to limit the catch of salmon, other groundfish, and prohibited species. Though instituted as an experimental monitoring program, it has been continued annually to account for all catch in targeted whiting trip landings, enumerate potential discards, and accommodate the landing and disposal of non-sorted catch from these trips. Initially, the SHOP included at-sea samplers aboard shore-based whiting vessels. However, when an Oregon Department of Fish and Wildlife (ODFW) analysis of bycatch determined no apparent difference between vessels with and without samplers, sampler coverage was reduced to shoreside processing plants. In 1995, the SHOP's emphasis changed from a high observation rate (50% of landings) to a lower rate (10% of landings), and the SHOP increased emphasis on collection of biological information (e.g., otoliths, length, weight, sex, and maturity) from Pacific whiting and selected bycatch species (yellowtail rockfish, widow rockfish, sablefish, chub [Pacific] mackerel [*Scomber japonicus*], and jack mackerel [*Trachurus symmetricus*]). The required observation rate was decreased as studies indicated that fishtickets were a good representation of what was actually landed. Focus shifted again due to 1997 changes in the allocation of yellowtail rockfish and increases in yellowtail bycatch rates. Since then, yellowtail and widow bycatch in the shoreside whiting fishery has been dramatically reduced because of increased awareness by fishermen of the bycatch and allocation issues involved in the SHOP program.

The SHOP is a cooperative effort between the fishing industry and state and federal management agencies to sample and collect information on directed Pacific whiting landings at shoreside processing plants. Participating vessels apply for and carry an EFP issued by NMFS. Permit terms require vessels to retain all catch and land unsorted catch at designated shoreside processing plants. Permitted vessels are not penalized for landing prohibited species (e.g., Pacific salmon, Pacific halibut, and Dungeness crab), nor are they held liable for overages of groundfish trip limits. For additional information and complete reports go to: (www.dfw.state.or.us/MRP/hake/).

Since inception, an EFP has been adopted annually to allow suspension of at-sea sorting requirements in the shore-based whiting fishery, enabling full retention and subsequent port sampling of the entire catch. However, EFPs are intended to provide for limited testing of a fishing strategy, gear type, or monitoring program that may eventually be implemented on a larger fleet-wide scale and are not a permanent solution to the monitoring needs of the shore-based Pacific whiting fishery. In 2008, the Council and NMFS implemented a monitoring program to maximize retention opportunity without the use of the EFP process. Electronic monitoring of catches through the use of deck cameras and human at-sea observers were used, prior to catch share implementation to ensure maximized retention of catch at sea. Since the inception of the IFQ Program in January, 2011, 100% observer coverage has replaced electronic deck monitoring.

Data Collection Programs – Recreational sectors

Monitoring Recreational Catch

Recreational catch is monitored by the states as it is landed in port. These data are compiled by the PSMFC in the RecFIN database. The types of data compiled in RecFIN include sampled biological data, estimates of landed catch plus discards, and economic data. Descriptions of the RecFIN program, state recreational fishery sampling programs in Oregon and Washington, and the most recent data available to managers, assessment scientists, and the general public, can be found on the PSMFC web site at: (http://www.psmfc.org/Recreational_Fisheries_Information_Network_RecFIN).

Central California Marine Sport Fish Project

The CDFG has been collecting angler catch data from the CPFV industry intermittently for several decades in order to assess the status of the nearshore California recreational fishery. The project has focused primarily on rockfish and lingcod angling and has not sampled salmon trips. Reports and analyses from these projects document trends by port area in species composition, angler effort, catch, and, for selected species, Catch Per Unit Effort (CPUE), mean length, and length frequency. In addition, total catch and effort estimates are based on adjustments of logbook data by sampling information. Before 1987, catch information was primarily obtained on a general port basis from dockside sampling of CPFVs, also called party boats. This did not allow for documentation of specific areas of importance to recreational anglers and was not sufficient to assess the status of rockfish populations at specific locations.

CPFV operators in California are required by law to record total catch and location for all fishing trips in logbooks provided by the CDFG. However, the required information is too general to use in assessing the status of the multispecies rockfish complex on a reef-by-reef basis. Rockfish catch data are not reported by species, and information on location is only requested by block number (a block is an area of 100 square miles). Many rockfish tend to be residential, underscoring the need for site-specific data. Thus, there is a strong need to collect catch information on board CPFVs at-sea. However, locations of specific fishing sites are often not revealed for confidentiality reasons.

In May 1987, the Central California Marine Sport Fish Project began on board sampling of the CPFV fleet. Data collection continued until June 1990, when state budgetary constraints temporarily precluded further sampling, resumed in August 1991, and continued through 1994. The program depends on the voluntary cooperation of CPFV owners and operators. Angler catches on board central and northern California CPFVs were sampled from 14 ports, ranging from Crescent City in the north to Port San Luis (Avila Beach) in the south.

Oregon Marine Recreational Observation Program

In response to depleted species declarations and increasing concerns about fishery interactions with these species, ODFW started this program to improve understanding of recreational impacts. There were three objectives to this program: (1) document the magnitude of canary rockfish discard in the Oregon recreational fishery; (2) improve the biological database for several rockfish and groundfish species; and (3) gather reef location information for future habitat mapping. A seasonal sampler was stationed in each of the ports of Garibaldi, Newport, and Charleston to ride recreational groundfish charter vessels coastwide in Oregon from July through September, 2001. The Garibaldi sampler covered boats out of Garibaldi, the Newport sampler covered both Newport and Depoe Bay, and the Charleston sampler covered Charleston, Bandon, and Brookings charter vessels. During a typical day, the sampler would ride a five to eight hour recreational groundfish charter trip and spend the remainder of the day gathering biological and genetic data dockside from several rockfish and groundfish species for which little is known, mostly due to their infrequency in the catch. The sampler records locations of fishing sites by handheld GPS for future use by the Habitat Mapping Project of the ODFW Marine Resources Program. Results from this program have been incorporated into recreational fishery modeling by ODFW. This program has continued and expanded to document the magnitude of discard of all groundfish species, not just canary rockfish. For more information on this program as well as other fishery research and survey programs, see the ODFW Marine Resources Program website at: (www.dfw.state.or.us/MRP/).

WDFW Groundfish At-Sea Data Collection Program

The WDFW At-Sea Data Collection Program was initiated in 2001 to allow fishery participants access to healthier groundfish stocks while meeting the rebuilding targets of depleted stocks and to collect bycatch data through an at-sea sampler program. The data collected in these programs could assist with future fishery management by producing valuable and accurate data on the amount, location, and species composition of the bycatch of rockfish associated with these fisheries, rather than using calculated bycatch assumptions. These data could also allow the Council to establish trip limits in the future that maximize fishing opportunities on healthy stocks while meeting conservation goals for depleted stocks.

In recent years, WDFW has implemented its At-Sea Data Collection Program through the use of federal EFPs. In 2001, 2002, 2003, and 2004, WDFW sponsored and administered a trawl EFP for arrowtooth flounder and petrale sole, and in 2002, WDFW also sponsored a mid-water trawl EFP for yellowtail rockfish. The primary objective for these experimental fisheries was to measure bycatch rates for depleted rockfish species associated with these trawl fisheries. Fishery participants were provided access to healthier groundfish stocks and were constrained by individual vessel bycatch caps. State-sponsored samplers were used to collect data on the amount of rockfish bycatch caught on a per tow basis and to ensure the vessel complied with the bycatch cap; therefore, vessels participating in the EFP were required to have 100% sampler coverage. In 2003 and 2004, WDFW sponsored a longline EFP for spiny dogfish that also required 100% sampler coverage to measure the bycatch rate of depleted rockfish species associated with directed dogfish fishing.

WDFW Ocean Sampling Program

In addition to the At-Sea Data Collection Program, WDFW collects at-sea data through the Ocean Sampling Program. The WDFW recreational observer program is designed to observe catch on salmon charter trips only. Groundfish are occasionally observed on these trips but biological data is not collected. The estimated discard weights are derived from landed retained catch. The at-sea portion is not intended to be an observer program for the purposes of enumerating the bycatch alone, but is coupled with shore-based sampling of anglers to calculate an estimated discard weight. At-sea samplers record biological information from discarded species. Shore-based creel surveys of anglers provide the estimate of total number of discards. Combining these two data sources yields estimates of the weight of total fishery discard by species.

Data Collection Programs – Tribal sectors

Tribal Observer Program

Tribal-directed groundfish fisheries are subject to full rockfish retention. For some rockfish species where the tribes do not have formal allocations, trip limits proposed by the tribes are adopted by the Council to accommodate incidental catch in directed fisheries (i.e., Pacific halibut, sablefish, and yellowtail rockfish). These trip limits are intended to constrain direct catches while allowing for small incidental catches. Incidental catch and discard of depleted species is minimized through the use of full rockfish retention, shore based sampling, observer coverage, and shared information throughout the fleets regarding areas of known interactions with species of concern. Makah trawl vessels often participate in paired tows in close proximity where one vessel has observer coverage. If landings on the observed vessel indicate higher than anticipated catches of depleted species, the vessels relocate and inform the rest of the fleet of the results (Joner 2004). In order to avoid depleted species, fleet communication is practiced by all tribal fleets.

Additional Relevant Data Collection Programs

Stranding network

Under the Marine Mammal Protection Act (MMPA) of 1972, NOAA Fisheries' regional marine mammal stranding networks were established in the early 1980's and are composed of cooperating scientific investigators, academic institutions, volunteer individuals and non-government organizations, wildlife and fisheries agencies, and federal, state and local enforcement agencies. Network participants are trained in systematic data collection and are experienced in handling a variety of marine mammal stranding related tasks. The regional stranding networks are administered via authority delegated to the regional administrators in each of the six NOAA Fisheries regions (Northeast, Southeast, Alaska, Northwest, Southwest, and Pacific Islands). The 1992 amendments to the MMPA established the Marine Mammal Health and Stranding Response Program (MMHSRP) and began the systematic compilation of regional stranding data and standardization of stranding response practices on a national level.

Two regional stranding networks operate on the Pacific coast of the continental U.S. The northwest network responds to marine mammal and sea turtle stranding events along the Washington and Oregon coasts, and the southwest network responds to events along the California coast. The stranding networks receive reports of stranding events from the public and respond to investigate and collect standardized data. Coordinators in each region verify and enter the data into a national database to establish baseline information on marine mammal populations and monitor their health. The reporting form containing prompts for standardized data collection is accessible online at: http://www.nmfs.noaa.gov/pr/pdfs/health/levela.pdf. These standardized data include evidence of human interaction, such as signs of fishery interaction or boat collision. Where there are findings of human interaction an additional report is generated that includes more details about the observations that support the determination of the specific interaction type.

For data quality control, specific reporting protocols have been developed for use by the networks and regional coordinators. The collection of stranding data, in the field, is strongly influenced by the condition of the remains when examined as well as environmental factors such as severe weather or tidal fluctuation at the exam location. These factors can obscure the detection of human interaction evidence thus affecting the confidence in a human interaction determination. To assist with data interpretation, the MMHSRP protocols assign four confidence levels to the field data; 1) unconfirmed – low; 2) confirmed – minimum; 3) confirmed – medium; and 4) confirmed – high. Confirmed reports are used to inform the periodic updates to marine mammal stock assessment reports and annual modifications to the MMPA list of fisheries.

NOAA Fisheries is completing policy development for analyzing and using marine mammal/human interaction data in stock assessment reports and list of fisheries decisions. Regional fisheries science centers compile information on marine mammal/human interactions from a variety of source including reports from regional stranding coordinators, fisher self reports, fisheries observer data and other reports from the field. Although the publication of stock assessment reports and list of fisheries decisions are periodic (annul or semi-annual) the compilation of data from the various sources, including regional stranding data, may lag behind the current reporting cycle by up to two years.

Fishery Enforcement Monitoring

Enforcement of fishery regulations has become increasingly complex with the addition of large closed areas, smaller cumulative trip limits and bag limits, and depth-based closures for commercial and recreational fisheries. At the same time, decreased catch limits and the need to rebuild depleted stocks has placed additional importance on controlling and monitoring fishery-related mortality. Enforcement agencies continue to use traditional methods to ensure compliance with groundfish fishery regulations, including dockside sampling, at-sea patrols, and air surveillance. Vessel Monitoring Systems (VMS) enhance, rather than replace, traditional enforcement techniques. Recent declines in enforcement agency budgets, combined with increased regulatory complexity, have stressed the ability to adequately monitor fisheries for regulatory compliance. In response, NMFS implemented a VMS monitoring program, which includes satellite tracking of vessel positions and a declaration system for those vessels legally fishing within an RCA. VMS was initially implemented on 1 January 2004, and is currently required on all vessels participating in the groundfish fishery with a limited entry permit. In November 2005, the Council recommended expansion of VMS requirements to all commercial vessels that take and retain, possess, or land federally-managed groundfish species taken in federal waters or in state waters prior to transiting federal waters. Additionally, to enhance enforcement of closed areas for the protection of groundfish essential fish habitat, the Council recommends requiring VMS on all non-groundfish trawl vessels, including those targeting pink shrimp, California halibut, sea cucumber, and ridgeback prawn. Implementation of expanded VMS requirements is recommended to coincide with implementation of regulations for the protection of groundfish habitat but, no sooner than 1 January 2007.

Detailed descriptions of VMS and the analyses of VMS monitoring alternatives are contained in an EA prepared by NMFS and were presented to the Council in support of decisions to first implement and later expand the VMS monitoring program (NMFS 2003). Additional information on VMS, including links to the supporting NEPA documentation, can be found on the Council web site at: (www.pcouncil.org/groundfish/gfvms.html#info).

Anticipated Fishing Effort Changes

Most of our information on interactions between the WCGF and ESA-listed species has been obtained over the period from 2002–2010, corresponding to initiation of federal observer programs (see above). However, fishing effort patterns and the associated exposure of listed species to fishery effects is subject to change through a variety of factors, including the population dynamics of fish species and behavioral drivers of fishing fleets through economic factors, such as fuel prices, market dynamics, and regulations. Of these, regulatory drivers are the most foreseeable, and an assessment of how listed species exposure may be impacted is provided below. Due to limitations in predictive capability, the assessment is qualitative. Precise characterization of effort shifts is a function of monitoring and is performed through retrospective analysis. NMFS and the Council track changes in the fishery through the monitoring programs described in this document. The information is compiled in reports submitted throughout the year to the Council and is available for public review. In addition, the response of fishing behavior to individual quota programs, as implemented under amendments 20 and 21, is an area of increased research that is expected to be refined over time and may lead to improvements in predicting effort shifts (for example, see Toft et al. 2011; Kaplan unpublished; and Marchal et al. 2009).

Regulatory Induced Effort Shifts

NMFS and the Council implemented a trawl rationalization program in January 2011 that represents a significant change to management of the groundfish fishery. Of importance to listed species are potential changes in fishing effort profiles by time, area, and gear type. The trawl rationalization program is a limited access privilege program designed to reduce capacity and improve the management, accountability, economic, and environmental stability of the groundfish fishery by vesting the conditional privilege of catch shares for a predetermined quantity of fish with permit holders. The program was implemented in 2011 by amendments 20 and 21 to the FMP and accompanying regulations. The Council's goal for the program is to:

> *Create and implement a capacity rationalization plan that increases net economic benefits, creates individual economic stability, provides for full utilization of the trawl sector allocation, considers environmental impacts, and achieves individual accountability of catch and bycatch.*

The objectives supporting this goal are to:

- Provide a mechanism for total catch accounting;
- Provide for a viable, profitable, and efficient groundfish fishery;
- Promote practices that reduce bycatch and discard mortality, and minimize ecological impacts;
- Increase operational flexibility; minimize adverse effects from the program on fishing communities and other fisheries to the extent practical;
- Promote measurable economic and employment benefits through the seafood catching, processing, distribution elements, and support sectors of the industry;
- Provide quality product for the consumer; and,
- Increase safety in the fishery.

The trawl rationalization program is in its earliest stages; however, it may influence the exposure of listed species to the fishery by incentivizing fishermen to change their historical fishing patterns relative to gear type and the time and location where it is deployed. The trawl rationalization program is also expected to reduce the overall amount of groundfish trawl effort by 50% to 66%; however, this reduction may be unevenly distributed (Lian et al. 2009). The program components that are most likely to influence effort patterns are allocation, gear switching, qualifying years, and quota transfer between fishermen. These components are discussed below.

Allocation

Amendment 21 allocates fixed percentages of allowable harvest by species to sectors. Because sectors are defined primarily by gear type, allocation may have the general effect of increasing or decreasing listed species exposure to a specific fishing gear and its associated impact potential. For the most part however, this is not expected to be the case. In general, the allocations are based on catch history from 2003–2005. This time period is recent enough that no significant changes are expected. There are three exceptions: starry flounder; "other flatfish;" and chilipepper rockfish south of 40º10'N latitude, for which amendment 21 allocates a higher percentage to the non-trawl sector than accounted for during the qualifying period. This may result in an increase in pot and bottom-longline gear fishing effort; however, it is impossible to predict the magnitude of such an increase given available data. As described above, NMFS is actively monitoring changes in the fishery that result from the trawl rationalization program and producing reports that will be incorporated into the ESA consultation process as it unfolds.

Gear Switching

Within the trawl rationalization program, vessels are no longer required to use a specific gear type. Vessels that have been limited to trawl gear may now opt to use non-trawl gear. As with other elements of the trawl rationalization program, it is unknown how this will influence fishing effort profiles. Market analysis suggests it may be economically beneficial for some fishermen to harvest sablefish by bottom-longline instead of trawl; however, it is not yet known if this will occur or, if it does, the magnitude of change. As mentioned above, starry flounder, "other flatfish," and chilipepper rockfish south of 40º10'N latitude have been allocated to non-trawl fisheries in excess of historical amounts. Similar to sablefish, it is not possible to determine if this will result in a net increase in non-trawl effort. NMFS is actively monitoring changes in the fishery that result from the trawl rationalization program and producing reports that will be incorporated into the ESA consultation process as it unfolds.

Qualifying Years

Determination of "qualifying years" for trawl rationalization has the potential to create geographic shifts that may influence interactions with listed species. Qualifying years are the period of time that a permit must have been active to be eligible for participation in the trawl rationalization program. After considering several possible time periods to serve as the qualifying period, the Council recommended the years 1994–2003 for non-overfished species. These years represent the period of time from the beginning of the license limitation period through the announcement of the trawl rationalization control date. Dates prior to 1994 would not have permit histories because the Limited Entry system under which the permits were issued was not implemented until 1994. Other potential start dates between 1994 and 2003 were considered, including 1997 (the first year of fixed allocations among the three whiting sectors), 1998 (to exclude older histories), 1999 (the year of the first major reductions in response to overfished determinations), and 2000 (the year disaster was declared and fishing opportunities were significantly constrained and modified). The Council also considered 2004 as a later end date to the qualifying period, but determined that using 2004 would reward speculative entrants who chose to ignore the control date, create perceptions of inequity, and undermine the ability of the Council to use control dates in the future. The recommended range of years from 1994–2003 would include fishing patterns from under a variety of circumstances, would recognize long-time users of the fishery, and is intended to mitigate disruptive effects experienced by communities as a result of geographic effort shifts.

Quota Transfer

Permit holders with individual quotas may sell or transfer quota under the new program rather than harvest it themselves. Early research indicates this may reduce overall effort as quota is transferred to the most efficient and profitable operations and consolidate effort in areas with high relative catch rates (Toft et al. 2011). The extent to which these changes manifest are a function of monitoring and are tracked through the data collection programs described above.

Summary of Potential Shifts in Fishing Effort

Fishing patterns are a function of multiple variables, the most significant of which is a recent implementation of the trawl rationalization program. The program may incentivize fishermen to increase fixed gear effort in patterns that deviate from historical norms. The magnitude of this deviation is not predictable; however, NMFS and the Council actively monitor fishing effort and produce periodic reports that will be available as the ESA consultation process unfolds.

Chapter 3: Whales

Introduction

In this section we briefly describe several issues and approaches that are common to each whale species. For most species, there are three primary data sources describing known or potential interactions between whales and the WCGF fishery: 1) the A-SHOP and WCGOP observer programs (Chapter 2), 2) data from the NWR and SWR stranding networks (Chapter 2 and Appendix C), and 3) information on spatial and temporal overlap between the species and the fisheries (Appendix B).

The proportion of fishing activity observed by the observer programs varies considerably among sectors (see Table 6 -- Table 9) and ranges from essentially 100% (at-sea hake catcher/processor sector) to 0% (some parts of the fixed gear sector in some years). In addition, some components of the fixed gear fishery involve leaving gear unattended (see Chapter 2). Large whales can swim considerable distances after becoming entangled in such gear, so mortality or injuries may be unobserved in such fisheries even if observers are on board. The potential for unobserved mortality due to entanglement in pot/trap gear introduces considerable uncertainty into any evaluation of the impacts of these fisheries on large whales.

Over the period from 2002–2009, there was only a single fishery interaction with a large whale reported by the A-SHOP and WCGOP observer programs (collision between a fishing boat and a sperm whale; Jannot et al., 2011). The lack of observed interactions with those components of the fishery that have moderate to high observer coverage (at-sea hake catcher/processor and most parts of the bottom trawl fisheries) indicates that direct interactions between these components of the WCGF fishery and large whales are rare. However, most components of the open access fixed gear portion of the WCGF fisheries have very low observer coverage (Table 9), so the lack of reported interactions with fixed gear such as traps or pots does not indicate that such interactions do not occur. Indeed, the observation of stranded or dead whales with trailing gear or evidence of gear-related scaring indicates that some unobserved fishing mortality does occur, although few of these deaths can be directly linked to a specific fishery (Appendix C).

Estimates of impacts due to gear entanglement in fixed gear fisheries are therefore minimum estimates, due to the difficulty of observing these events, particularly for fisheries in which gear is left to fish unattended (see Chapter 2). In the Gulf of Maine, for example, the annual rate of new entanglement scarring of humpback whales has been estimated to be 12.1% (Robbins and Mattila, 2004), and the total mortality rate due to entanglement at roughly >3% annually (Robbins et al., 2009), a rate ~10X higher than has been directly observed (Waring et al., 2009).

In evaluating the risks for entanglement in fixed gear, we therefore must rely on more indirect information, such as the degree of spatial overlap with the fishery (Appendix B). In some cases we also evaluated the recently rate of population increase of a species and compared this to the rate expected in the absence of human-caused mortality. In cases where the observed rate of increase is similar to what would be expected in the absence of substantial external mortality, we concluded that fishery entanglement was unlikely to be substantially impacting the population. However, in the absence of more direct estimates of mortality, there will continue to be some uncertainty about the true impacts of unobserved fisheries and entanglement in unattended gear.

For whales (and all other marine mammals) another common method of evaluating the risk imposed by a particular level of mortality is the concept of Potential Biological Removal (PBR) (Barlow et al., 1995). The PBR concept is a key element in conducting assessments under the Marine Mammal Protection Act, and it is intended to represent the maximum level of anthropogenic mortality consistent with the unimpeded recovery of depleted stocks. PBR is calculated as N_{min}* 0.5 R_{max} * F, where N_{min} is the minimum current population size, R_{max} is the maximum annual rate of increase for the species or stock, and F is a recovery factor that ranges from 0.1 to 1 depending on the conservation status of the stock. We therefore review recent estimates of PBR and associated human-caused mortality for all of the marine mammal species we evaluated (Carretta et al. 2010).

*Humpback whale (*Megaptera novaeangliae*)*

General biology[5]

Humpback whales are a species of baleen whale characterized by long pectoral flippers, distinct ventral fluke patterning, dark dorsal coloration, a highly varied acoustic call, and a diverse repertoire of behavior. Coloring of the ventral surface varies from white to marbled to fully black. They are among the larger whales, weighing over 40 tons and with mature lengths of 13–15 m. In the Pacific Ocean, females bear their first calves at between 8–16 years of age, and the maximum life-span is at least 50 years, with an average generation time of 21.5 years. Calving intervals are from 2–3 years following an 11-month gestation period. Humpback whales feed on both krill and small schooling fish, employing both solitary and group foraging strategies.

Range, migratory behavior, and stock structure

Humpback whales are found in all oceans of the world with a broad geographical range from tropical to temperate waters in the northern hemisphere and tropical to waters near the ice edge in the southern hemisphere. All populations undertake seasonal migrations between their temperate and sub-tropical winter calving and breeding grounds and high latitude summer feeding grounds. Humpback whales typically occur on the feeding grounds during the summer and fall months.

In the North Pacific, the primary breeding grounds are located in coastal areas of Central America, Mexico, the Baja Peninsula (Mexico), the Revillagigedos Islands (Mexico), Hawaii, the Philippines, the islands of Ogasaware and Okinawa, and an unidentified additional Western Pacific breeding ground (Calambokidis et al., 2008; Fleming and Jackson, 2011). The breeding populations differ in their genetic characteristics (Baker et al., 1998; Baker and Steel, 2010), and photo-id-based mark/recapture studies indicate a high, but not complete, degree of individual fidelity to one of the four general breeding areas (Mexico, Central America, Hawaii, Asia; Calambokidis et al. 2008).

Feeding areas include coastal waters across the Pacific Rim from California to Japan. Humpback whales are commonly observed off the California, Oregon and Washington coasts during the spring, summer and fall months (Figure 6), and they have also been detected off California (Forney and Barlow 1998) and Washington (Oleson et al. 2009, NWFSC unpubl. data) during the winter. The whales feeding off of California and Oregon are primarily from the Mexican breeding area, with smaller contributions from Central America. The whales feeding off of Washington and Southern British Columbia (BC) are also from the Mexican and Central American breeding areas, but include in addition a significant number of individuals from the Hawaiian breeding area (Calambokidis et al. 2008).

---

[5] Unless otherwise noted, all of the material in this section was drawn from the following recent review: Fleming A, Jackson J, 2011. Global review of the humpback whale (*Megaptera novaeangliae*). NOAA-NMFS-SWFSC Tech Memo NMFS-SWFSC-474.

Recent efforts indicate that there is relatively high site fidelity of individuals to broad feeding grounds (Calambokidis et al., 2008), but movements likely occur within these feeding areas. No direct information is available on the routes used by humpbacks from their West Coast feeding areas to breeding areas. However, it can be inferred from their known destinations, based on photo-id data, that in Oregon and California their movements are probably primarily coastal as they move to Mexico and Central America. Limited information is available on the routes of whales tagged on their Mexican breeding ground, but the movements of one whale to the BC feeding ground was generally near or westward of the continental slope (Lagerquist et al., 2008). This coastal migration pattern may be similar for the portion of the northern Washington animals that also breed in these areas, but a substantial proportion of the animals observed in this area winter in Hawaii, and these animals obviously must have a less coastal migration pattern.

Habitat use

West Coast humpback whales migrate from breeding grounds in Mexico and Hawaii to the West Coast of the United States and British Columbia to feed in the summer. Thus, while whales do occur throughout the shelf waters of the U.S. West Coast, they tend to aggregate off central California, Oregon, and the northwest coast of Washington State (Figure 6). In California, the whales tend to use the Monterey Bay and Gulf of the Farallons (Barlow et al., 2009; Benson, 2002; Benson et al., 2002; Forney, 2007; Kieckhefer, 1992). Off the northwest coast of Washington, whales have been primarily observed to occur east of the Barkley Canyon, between the La Perouse Bank and Nitnat Canyon, and on the shelf edge near the Juan de Fuca Canyon (Figure 6; Calambokidis et al., 2004; Dalla Rosa, 2010). In particular, the whales appear to occur primarily on the periphery of the Juan de Fuca Eddy (Dall Rosa 2010). In northern California and southern Oregon, humpbacks appeared to be associated with the inside edge of the coastal upwelling front (Tynan et al., 2005).

Critical habitat

Critical habitat has not been identified for this species. However, a NOAA National Marine Sanctuary was specifically established to protect this species' Hawaii wintering ground, and the Monterey Bay, Gulf of the Farallons/Cordell Bank, and Olympic Coast National Marine Sanctuaries all encompass important feeding grounds.

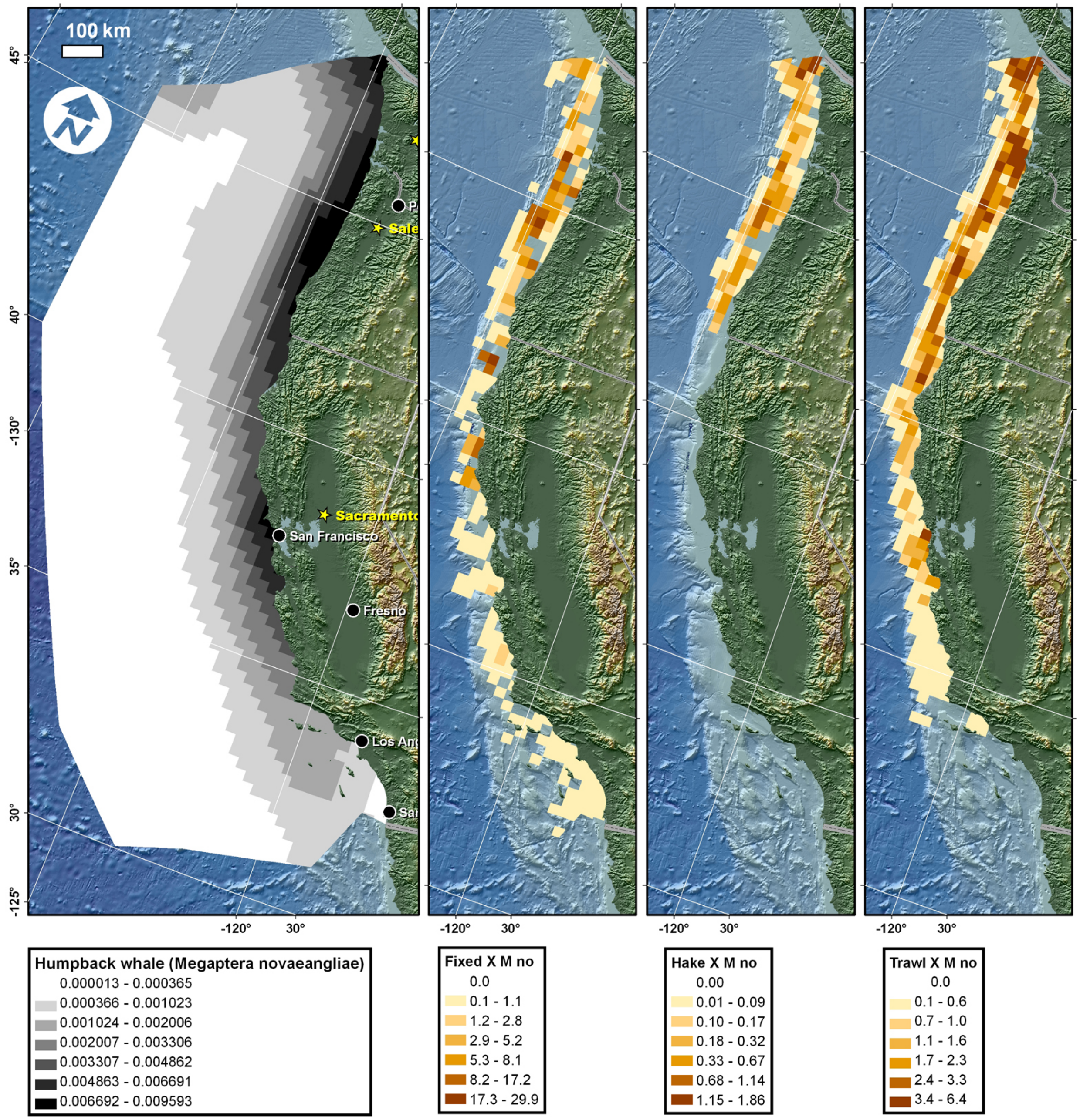


Figure 6: Left panel: Mean predicted humpback whale density (number of animals/km^2), based on surveys conducted from June through November, from 1991 – 2005 (data from Barlow et al. 2009). Ship-based cetacean and ecosystem assessment surveys of humpback sighting locations were extrapolated to a regular grid (25 km resolution) for each year and were smoothed with geospatial methods to obtain a continuous grid of density estimates for the California Current Ecosystem. Right panels: Overlap indices with three fishery sectors: fixed gear, hake trawl, and bottom trawl. Indices are in units of animal hours/km^2. See Appendix B for details.

Status

Humpback whales were listed as endangered under the ESA in 1970. A Recovery Plan was finalized for this species in 1991 (NMFS, 1991). NMFS is currently conducting a status review of the species (Federal Register: 74 FR 40568).

Abundance and trend

The most recent (2004–2006) population estimate of humpback whales in the North Pacific Ocean is 21,808 (CV=0.04) (Barlow et al., 2011), which is higher than the estimated pre-exploitation abundance of ~15,000, although there is a great deal of uncertainty about the latter estimate (Rice, 1978). Estimates of the breeding population sizes during the 2004–2006 time period are approximately 10,000 (Hawaii), 6,000-7,000 (Mexico, including Baja and the Revillagigedos Islands), 500 (Central America), and 1,000 (Western Pacific) (Calambokidis et al. 2008). For management under the Marine Mammal Protection Act, humpback whales stocks are defined based on feeding areas, with the whales feeding off of California, Oregon, and Washington currently considered one stock (Carretta et al., 2010). The estimated abundance of this feeding stock as of 2007/2008 was 2,043 (CV=0.10) (Carretta et al., 2010).

For the North Pacific populations as whole, Calambokidis et al. (2008) estimated an average annual increase of 6.8% over the period from 1966 to 2006, based on an estimated post-exploitation abundance of 1,400 in 1966. The same authors estimated a slightly lower rate of 4.9%, based on the only other North Pacific-wide abundance of estimate of 9,819 in 1991–1993. The Hawaiian breeding population was estimated to be increasing at 5.5–6.0% annually over the period from 1991–1993 to 2006. The annual growth rate for the CA-OR-WA feeding stock is estimated to be 7.5%, based on abundance estimates from the 1980s, 1990s, and 2000s (Carretta et al. 2010). The point estimates of the maximum expected rate of annual increase for the species based on its life-history pattern range from 7.3–8.6% (Zerbini et al., 2010), with a maximum plausible rate (upper 99% confidence interval of the expected maximum) of 11.8% annually.

Where they have been measured, most Southern Hemisphere populations have been increasing at annual rates of 7–9% since the early- to mid-1990s (reviewed by Fleming and Jackson 2011). The Gulf of Maine feeding population has been estimated to be increasing at a lower rate of ~3% annually from 1979 to 1993 (Stevick et al., 2003).

Threats (from Recovery Plan or listing documents)

Humpback whales face a variety of threats, depending on the region in which they occur. Threats listed in the Recovery Plan include entrapment and entanglement in fishing gear, collisions with ships, acoustic disturbance, habitat degradation, and competition for resources with humans (NMFS 1991).

Fishery impacts

Fisheries may affect humpback whales through several mechanisms, including vessel collisions, physical disturbance, acoustic disturbance, entanglement in nets or lines, pollution from exhaust or spills, and direct or indirect reduction of prey (NMFS 1991).

Impacts, all fisheries

California, Oregon, Washington – There were been 28 reported entanglements of humpback whales in fishing gear off the West Coast from 2000 to 2007 (SWR and NWR stranding network; Alison Agness, personal communication to M. Ford August 28, 2009). Of these, 15 involved pot gear, 6 involved net gear, and 7 involved gear of unknown type. In most of these cases, the final status of the entangled animal was unknown. Based on these data, Carretta et al. (2010) estimated that a minimum of 3.2 humpback whales per year were killed or seriously injured due to entanglement over the 2004–2008 time period. Carretta et al. (2010) also reported a minimum of 0.4 deaths per year in this area due to ship strikes.

Mexico*, Central America* – Carretta et al. (2010) summarized information on fishery interactions in Mexico as follows:

> Drift gillnet fisheries for swordfish and sharks exist along the entire Pacific coast of Baja California, Mexico and may take animals from the same population. Quantitative data are available only for the Mexican swordfish drift gillnet fishery, which uses vessels, gear, and operational procedures similar to those in the U.S. drift gillnet fishery, although nets may be up to 4.5 km long (Holts and Sosa-Nishizaki 1998). The fleet increased from two vessels in 1986 to 31 vessels in 1993 (Holts and Sosa-Nishizaki 1998). The total number of sets in this fishery in 1992 can be estimated from data provided by these authors to be approximately 2,700, with an observed rate of marine mammal bycatch of 0.13 animals per set (10 marine mammals in 77 observed sets; Sosa-Nishizaki et al. 1993). This overall mortality rate is similar to that observed in California driftnet fisheries during 1990–95 (0.14 marine mammals per set; Julian and Beeson, 1998), but species-specific information is not available for the Mexican fisheries. Previous efforts to convert the Mexican swordfish driftnet fishery to a longline fishery have resulted in a mixed-fishery, with 20 vessels alternately using longlines or driftnets, 23 using driftnets only, 22 using longlines only, and 7 with unknown gear type (Berdegué 2002).

Alaska and Hawaii – Angliss et al. (2010) estimated that the minimum commercial fishery-related mortality of the Central Pacific stock was 3 per year, based on observer data from Alaska and Hawaii and stranding information from Alaska. Based on photographic analysis of scarring patterns, Neilson et al. (2009) estimated that 71% of humpback whales in northern Southeast Alaska had been previously entangled, and that 8% (2/26) of the whales in a specific location received new scars between 2003 and 2004.

Impacts, WCGF fisheries

Humpback whales occur at highest densities near the coast, and therefore generally have a relatively high degree of spatial overlap with WCGF fisheries (Figure 6). Among the three fisheries categories, the highest overlap index was with the fixed gear fishery, followed by the mid-water trawl hake fishery and the bottom trawl fishery (see Figure CET16 in Feist and

Bellman (2011), Appendix B). For the fixed gear portion of the fishery, peak areas of overlap (>17 animals hours/km^2) occur north of Cape Mendocina, off the central Oregon coast, and off the Columbia River mouth (Figure 6). For the trawl fishery, the highest overlap indices occur along the north portion of the coast from Cape Mendocina to Cape Flattery, and areas of overlap are > 3 animals hours/km^2 (Figure 6). The highest overlap indices for the hake fishery occur near Cape Flattery, and are < 2 animal hours/km^2 (Figure 6).

Although there is clearly some spatial overlap between humpback whales and the WCGG fisheries, particularly the fixed gear sector, over the period from 2002–2009, there were no observed fishery interactions with humpback whales reported by the A-SHOP or WCGOP observer programs (Jannot et al., 2011). Note, however, that most components of the fixed gear portion of the WCGF fisheries have very low observer coverage (see Fisheries Description Section), so the lack of reported interactions in low-coverage fisheries does not indicate that such interactions do not occur. Of the entanglements reported by the NMFS Southwest Region and Northwest Region stranding programs, only one could definitively be identified as being caused by the WCGF fishery (entanglement in a sablefish pot). Most of the entanglements could not be associated with a specific fishery, but are mostly characterized as pot/trap gear from unidentified fisheries. Some of these may therefore have involved pot/trap gear associated with the WCGF fishery.

The estimated impact due to gear entanglement is a minimum estimate, due to the difficulty of observing these events, particularly for fixed gear fisheries in which gear is often left unattended for periods of hours to days (see Chapter 2). In the Gulf of Maine, for example, the annual rate of new entanglement scarring has been estimated to be 12.1% (Robbins and Mattila, 2004), and the total mortality rate due to entanglement at >3% annually (Robbins et al., 2009), a rate much higher than has been directly observed (Waring et al., 2009). Humpback whales in the North Pacific also have relatively high entanglement-associated scarring, with 40–50% observed whales in Mexico and Hawaii having entanglement scars compared to 48–57% in the Gulf of Maine (Robbins, 2010; Robbins and Mattila, 2004), suggesting that entanglement may also be common (and underreported) in the Pacific.

Habitat and trophic effects

WCGF fisheries target relatively large, commercially valuable fish species, including rockfish, hake, and various mid-water and bottom fish (see Chapter 2 Description of the Fisheries). Humpback whales feed on krill and small schooling fishes, such as anchovies and sardines, which are not impacted by the WCGF fisheries to any significant extent (NWFSC 2010). Indirect trophic effects of the WCGF fisheries are also expected to be minor and in fact may positively affect the abundance of krill through removal of predators (Appendix A).

Impact of WCGF fisheries on population growth rate

For the CA-OR-WA humpback stock, current (2008) N_{min} = 1878, R_{max} is assumed to 8%, and F = 0.3 (for an endangered species, with N_{min} > 1,500 and CV[N_{min}] < 0.50; Carretta et al. 2010; NMFS, 2005). This results in a PBR of 22.5, which is reduced to 11.25 if it is prorated for time spent in U.S. waters (Carretta et al. 2010).

The minimum estimate of total fishing mortality or serious injury (WCGF fisheries and other fisheries) is 3.2 per year over the 2004–2008 time period, due to entanglement in fixed gear (Carretta et al. 2010). If the true level of mortality associated with fisheries is close to the minimal estimate, this would suggest that takes from the WCGF fisheries have a very minor impact on the rate of population growth even under the very conservative assumption that all of this take could be attributed to WCGF fisheries. For example, at the current estimated growth rate (7.5%) and abundance (2,043), the population is growing at ~153 individuals annually. If one assumes that this would increase by 3.2 individuals in the absence of fishing, this translates into a reduction of the population growth rate of ~0.16%.

We took two different approaches for estimating the maximum upper bound mortality rate imposed by all fisheries on West Coast humpback whales. First, the difference between the estimated growth rate (7.5%) and maximum plausible growth rate for the species (11.8%) is 4.3%. Under the highly improbable assumption that fishing is the only source of non-natural mortality on the stock and that the stock is sufficiently below carrying capacity that it is increasing at its maximum rate, this value would be an upper bound on the maximum possible impact from fishing and would imply that in recent years, ~88 animals/year are killed due to fishing activities. The second approach was to assume that the estimated 3% mortality from entanglement for the Gulf of Maine stock (Robbins et al., 2009) is also representative of the CA-OR-WA stock. This would imply that in recent years, ~ 61 animals are killed annually due to fishing. Although there are currently no estimates of the annual rate of new scarring from entanglement for the CA-OR-WA stock, the proportion of all animals with scars is similar between the two stocks (Robbins and Matilla 2004, Robbins et al. 2009), which might imply that the rate of scarring from entanglement may be similar between the two areas. Both of the upper bound estimates are well above PBR and, if true, would suggest that total mortality from fishing is having a substantial impact on the population's growth rate.

The true level of impact is almost certainly between the upper and lower bounds, but it is probably much closer to the lower bound than the upper one. In particular, the maximum plausible growth rate of 11.8% is based on the 99th percentile of a distribution around a mean estimate (Zerbini et al. 2010). The authors of that estimate emphasize that "…such a high figure can be observed only with extreme and very optimistic life-history parameters" (Zerbini et al. 2010 p. 1233). The point estimates of the maximum plausible growth rate (7.3–8.6%) are in fact very close to the observed growth rate of the CA-OR-WA stock (7.5%), suggesting that this population is likely to be growing at close to its maximum rate and that mortality from fishing is therefore not substantially impacting its growth rate. The Gulf of Maine estimate of 3% mortality/year is also considered to be a "…crude, preliminary…" estimate by its authors (Robbins et al. 2009 p. 3), and becomes even more so when applied to an entirely different population.

Based on the information summarized above, we conclude that West Coast fisheries, including the WCGF fisheries, are imposing some additional (non-natural) mortality on humpback whales. The number of takes per year is likely to be somewhat higher than the observed number of 3.2 per year. However, the population has been increasing at a rate that is well within the bounds of the maximum intrinsic growth rate of the species, and its current abundance is arguably close to a level associated with recovery. From this, we conclude that recent impacts from fishing are not substantially impacting the population abundance or trend. The lack of substantial impacts on the CA/WA/OR stock, combined with generally increasing trends for humpback whales in the North Pacific and worldwide (Fleming and Jackson 2011), implies the WCGF fisheries are not having a significant impact on either the viability of the globally listed species or any of the Pacific feeding or breeding stocks.

*Sei whale (*Balaenoptera borealis*)*

General biology[6]

The sei whale is a typical sleek rorqual and is the third largest whale, following the blue and fin whales (Perry et al. 1999). At maturity, sei whales range from 12 to 18 m in length (Lockyer 1977, Martin 1983), and females are considerably larger than males (NMFS 2011). Sei whales in the Southern Ocean can be longer than 17 m and weigh up to 28,000 kg (Lockyer 1977). Those in the Northern Hemisphere are smaller than those in the Southern Ocean. Information on sei whale reproduction is based on data from various ocean basins. The mean age at attainment of sexual maturity is thought to be 8–10 years in both sexes (Lockyer and Martin 1983). Estimated sei whale gestation periods range from 10.75 months to just over one year, depending on the model of fetal growth that is selected and potentially, by population (NMFS 2011). The average calving interval is probably at least two years (Jonsgard and Darling 1977; Lockyer and Martin 1983).

In the North Pacific, sei whales feed along the cold eastern currents (Perry et al. 1999). Prey includes calanoid copepods, krill, fish, and squid. In addition to calanoid copepods and euphausiids, sei whales in the North Pacific are said to prey on "almost every gregarious organism occurring with large biomass," including pelagic squid and fish the size of adult mackerel (Kawamura 1982; Nemoto and Kawamura 1977). Some fish species in their diet are commercially important. Off central California, sei whales fed during the 1960s mainly on anchovies from June through August and on krill (*Euphausia pacifica*) during September and October (Clapham et al. 1997; Rice 1977). Flinn et al. (2002) found that copepods were the dominant prey type found in sei whales commercially harvested in British Columbia from 1963–1967. Euphausiids and a number of fish species, including saury, whiting, lamprey, and herring, were also present. Flinn et al. (2002) also found that utilization of some prey varied between years and by season (Flinn et al. 2002). Similarly, Tamura et al. (2009) found that sei whales sampled from 2000–2007 fed on 12 prey species, including three copepod, three euphasiid, five fish (including varieties of anchovy, saury, and mackerel), and one squid species. These authors also concluded that sei whales are opportunistic feeders with flexible diets; principal prey items differed between years and by area. Sei whales tend to prey principally on copepods in the northern part of the North Pacific and fishes and squids elsewhere.

Range, migratory behavior, and stock structure

Sei whales have a cosmopolitan distribution, but the population structure has not yet been well-defined (NMFS 2011). NMFS recognizes three Marine Mammal Protection Act (MMPA) stocks of sei whales: Eastern North Pacific Ocean, Western North Atlantic, and Hawaii (NMFS 2011). Rice (1998) identified two subspecies—the northern sei whale (*Balaenoptera borealis borealis*) and southern sei whale (*Balaenoptera borealis schleglii)*—whose ranges do not overlap. On a global scale, the populations in the North Atlantic, North Pacific, and Southern Hemisphere are almost certainly separate, and they may be further subdivided into geographical

[6] General Biology section largely drawn from (NMFS) National Marine Fisheries Service. 2011. Final Recovery Plan for the Sei Whale (*Balaenoptera borealis*). Prepared by the Office of Protected Resources National Marine Fisheries Service, Silver Spring, MD. December 2011.

stocks (NMFS 2011). However, to date there has been no effort to define subspecies or Distinct Population Segments (DPSs) for sei whales under the ESA.

Sei whales are found primarily in cold temperate to subpolar latitudes rather than in the tropics or near the poles (Horwood 1987). Sei whales spend the summer months feeding in subpolar higher latitudes and return to lower latitudes to calve in the winter. There is some evidence from whaling catch data of differential migration patterns by reproductive class, with females arriving at and departing from feeding areas earlier than males. For the most part, the location of winter breeding areas is unknown.

In the North Pacific Ocean, it is believed that sei whales occur mainly south of the Aleutian Islands (Leatherwood et al. 1982; Nasu 1974). In the eastern Pacific, sei whales range as far south as Baja California, Mexico, to Japan and Korea in the west (Andrews 1916; Horwood 1987), and have been observed in the Hawaiian Islands (Smultea et al. 2010). Sei whales have been observed off central California during the 1960s, mainly in the late summer and early fall (Rice 1974). They have also been observed off the west coast of Vancouver Island, British Columbia, from June through August (Pike and Macaskie 1969). Only five confirmed sightings of sei whales were made in California, Oregon, and Washington waters during extensive ship and aerial surveys between 1991–2005 (Hill and Barlow 1992, Carretta and Forney 1993, Mangels and Gerrodette 1993, VonSaunder and Barlow 1999, Barlow 2003, Forney 2007). Green et al. (1992) did not report any sightings of sei whales in aerial surveys of Oregon and Washington. Their offshore distribution along the continental slope (Gregr and Trites 2001) probably explains, at least in part, the infrequency of observations in shelf waters between northern California and Washington. The sei whale's tendency not to enter semi-enclosed marginal seas or gulfs, noted above for the North Atlantic, also applies in the North Pacific. They are much rarer than Bryde's whales in the Gulf of California, Mexico (Tershy et al. 1990), although they do occur there occasionally, usually in association with other rorqual species (Gendron and Rosales 1996). Few enter the Sea of Japan in spite of the very high primary production in portions of this sea (Nemoto and Kawamura 1977).

Habitat use

Sei whales are highly mobile, and there is no indication that any population remains in a particular area year-round. Sei whales undertake seasonal north/south movements, wintering at relatively low latitudes and summering at relatively higher latitudes (NMFS 2011). Yet, Sei whales do not tend to move to as high latitudes as do the other balaenopterids, and they also tend not to enter semi-enclosed water bodies, such as the Gulf of Mexico, the Gulf of St. Lawrence, Hudson Bay, the North Sea, and the Mediterranean Sea (NMFS 2011).

Throughout their range, sei whales occur predominantly in deep water; typically they are most common over the continental slope (e.g., CETAP 1982; Martin 1983; Mitchell 1975a; Olsen et al. 2009), shelf-breaks (COSEWIC 2003), or in basins situated between banks (e.g., Sutcliffe and Brodie 1977). Furthermore, studies suggest that sei whales are strongly associated with ocean fronts and eddies (Nasu 1966; Nemoto and Kawamura 1977; Skov et al. 2008). A similar affinity for oceanic fronts has been observed in sei whales in Antarctic waters (Bost et al. 2009). These whales may also use currents in large scale movements or migrations (Olsen et al. 2009).

Critical habitat

Due to the paucity of information on sei whale habitat use and data on environmental features that make areas important to sei whales, critical habitat has not yet been identified for this species.

Status

Most stocks of sei whales were reduced, some of them considerably, by whaling in the 1950s through the early 1970s (NMFS 2011). As a consequence, the sei whale has been listed as "endangered" under the Endangered Species Act (ESA) since its passage in 1973. A Recovery Plan for sei whales has recently been completed (NMFS 2011). Of the commercially exploited "great whales," the sei whale is one of the least well studied, and the current status of most sei whale stocks is poorly known (NMFS 2011). There is a need for improved understanding of the genetic differences among and between populations to determine stock structure, which is a prerequisite for assessing abundance and trends of specific stocks (NMFS 2011).

Abundance and trend

Ohsumi and Wada (1974) estimated the pre-whaling abundance of sei whales to be 58,000–62,000 in the North Pacific. Later, Tillman (1977) estimated the pre-whaling abundance to be 42,000 and reported that these whales were reduced to 20% (8,600 out of 42,000) of their pre-whaling abundance between 1963 and 1974. Because 500 to 600 sei whales per year were killed off Japan from 1910 to the late 1950s, the stock was presumably already below its carrying capacity level by 1963 (Tillman 1977).

The last assessment of North Pacific sei whales by the International Whaling Commission (IWC) Scientific Committee was in 1974 (IWC 1977). Abundance estimates from the two most recent line-transect surveys conducted in 2005 and 2008 off California, Oregon, and Washington waters out to 300 nmi are 74 (CV=0.88) and 215 (CV=0.71) sei whales, respectively (Forney 2007, Barlow 2010). The mean abundance (calculated as a geometric mean) of the 2005 and 2008 estimates is 126 (CV=0.53), and the estimated minimum abundance is 83 (Barlow 2010).

There are no data on trends in sei whale abundance in the eastern North Pacific. Although the population is expected to have grown since given protected status in 1976, the potential effects of unauthorized take (Yablokov 1994) and incidental ship strikes and gillnet mortality make this uncertain (Carretta et al. 2009). Furthermore, there are no estimates of the growth rate of sei whale populations in the North Pacific (Best 1993, as cited in Carretta et al. 2009).

Threats (from Recovery Plan or listing documents)

Stocks in the North Atlantic and North Pacific Ocean have been legally protected from commercial whaling for the last 10 or more years, and this protection continues. The current potential threats include collisions with vessels, reduced prey abundance due to overfishing and/or climate change, the possibility that illegal whaling or resumed legal whaling will cause removals at biologically unsustainable rates, and possibly, the effects of increasing anthropogenic ocean noise (NMFS 2011). Carretta et al. (2009) also identified the offshore drift gillnet fishery as the only fishery that is likely to take sei whales from the eastern North Pacific stock of sei whales, but reported that no fishery mortality or serious injuries have been observed. The draft Recovery Plan for sei whales also identified injury or mortality from gear entanglement related to the drift gillnet fishery as a potential threat but considered it to be low in severity, but with high uncertainty (NMFS 2011). The relative impact to recovery is also unknown but potentially low (NMFS 2011).

Fishery impacts

Fisheries may potentially affect sei whales through several mechanisms, including collisions with vessels, reduced prey abundance, and increased anthropogenic ocean noise (NMFS 2011). As stated previously, based on the species' distribution, the offshore drift gillnet fishery is the only fishery that is likely to directly impact sei whales from this stock, but no fishery mortality or serious injuries have been observed (Carretta et al. 2009). The average annual estimated take of sei whales is zero, but some gillnet mortality of large whales may be unobserved because whales can swim away with a portion of the net (Carretta et al. 2009). Total estimated fishery mortality is zero and therefore is approaching zero mortality and serious injury rate (Carretta et al. 2009). Ship strike from fishery-associated vessels is a potential impact. In fact, from 1980–2006, one sei whale death was attributed to blunt force trauma after being struck by a large seafood processing vessel from Dutch Harbor, Alaska (Douglas et al. 2008). Although sei whales appear in ship-strike databases (Laist et al., 2001), there is only a single record for that species recorded from California, Oregon, and Washington combined (Douglas et al. 2008). This may be due to the fact that sei whales are not commonly observed off the U.S. West Coast (Douglas et al. 2008). Although the occurrence is rare, it has the potential to impact the eastern North Pacific stock of sei whales. Carretta et al. (2009) reported that the total incidental mortality due to ship strikes (0.2 per yr) is greater than the calculated PBR (0.05).

Impacts, all fisheries

California, Oregon, Washington – There is potential for impact on eastern North Pacific Ocean stock of sei whales with fisheries in California, Oregon, and Washington. However, there have been no reported entanglements of these whales in fishing gear off these states (Carretta et al. 2009).

Mexico, Central America – There is no evidence that the western coasts of Mexico and Central America were ever highly frequented habitats by sei whales, and there are no data available to assess the impacts of those fisheries on sei whales.

Alaska and Hawaii – The Hawaiian stock of sei whales could be impacted by fisheries activities in Hawaii. There have been no reported entanglements of sei whales in fishing gear off the Hawaiian islands (Carretta et al. 2009), but there is very little data available, and it is insufficient to assess whether total fishery mortality is significant to the Hawaiian stock of sei whales. Fisheries in Alaska could also potentially impact the eastern North Pacific Ocean stock of sei whales, but there are no data available to assess those impacts. Given the low population size and unknown growth rate of sei whales, the impact of even low levels of interactions could be significant.

Impacts, WCGF fisheries

Throughout their range, sei whales occur predominantly in deep water; typically they are most common over the continental slope (e.g., CETAP 1982; Martin 1983; Mitchell 1975a; Olsen et al. 2009), shelf-breaks (COSEWIC 2003), or in basins situated between banks (e.g., Sutcliffe and Brodie 1977). Thus, there is a limited degree of overlap between the WCGF fisheries regions and current sei whale distribution, and consequently there is a limited potential for impacts on the eastern North Pacific Ocean stock of sei whales from ship strikes or entanglement associated with the shelf-oriented WCGF fisheries. Consistent with the low distributional overlap and the apparently very low densities of sei whales, there were no recorded fishery interactions with sei whales from 2002–2009 reported by the A-SHOP or WCGOP observer programs (Jannot et al. 2011). Note, however, that impacts in the low-coverage fixed gear components of the fisheries cannot be entirely ruled out.

Habitat and trophic effects

In the North Pacific Ocean, the trophic interactions of sei whales with other large marine vertebrates are complicated because of the diversity of prey taken by sei whales in this ocean basin (Kawamura 1980, 1982). Rice (1977) suggested that the euryphagous character of sei whales in the eastern North Pacific should allow them to take advantage of population declines of other mysticete whales by increasing and occupying vacated niches. It could also mean that they are more likely than their North Atlantic counterparts to be affected by, and to affect, commercial fisheries for finfish (NMFS 2011).

WCGF fisheries target relatively large, commercially valuable fish species, including rockfish, hake, and various mid-water and bottom fish (see Chapter 2 Description of the Fisheries). Sei whales feed on calanoid copepods, krill, fish, and squid. The dominant food for sei whales off California during June through August is the northern anchovy, while in September and October they mainly eat krill. Although some squid may incidentally be caught by WCGF fisheries, the other prey items consumed by sei whales are not likely to be significantly impacted by the WCGF fisheries (NWFSC 2010). Indirect trophic effects of the WCGF fisheries are also expected to be minor and in fact may positively affect the abundance of krill through removal of predators (Appendix A).

In the case of intensive commercial fisheries that target larger species, it may be possible to alter the ecosystem structure in a manner that causes an increase in the abundance of other species that feed on zooplankton, particularly small fishes with lower economic value (Kenney 2002). This could potentially impact sei whales by increasing competition for their lower trophic level food resources. However, since sei whales appear to have a varied diet and feed in higher latitudes, this scenario, if it did occur, would not likely impact the feeding grounds of these whales.

Impact of WCGF fisheries on population growth rate

Due to the paucity of data on population abundance and reproductive rates, combined with the rarity of observing sei whales in the WCGF fisheries regions, it is not possible to quantify an estimated impact of WCGF on population growth rate. However, the lack of observed interactions combined with the limited degree of spatial overlap between the species and the WCGF fisheries suggest any impacts are likely to be negligible.

*North Pacific Right whale (*Eubalaena japonica*)*

General biology[7]

Right whales are large baleen whales which grow to lengths and weights between 45 and 55 feet (13.7–16.8 m) and 70 tons (63.5 metric tons), respectively (NMFS 2006). Females are larger than males. North Pacific right whales attain larger maximum sizes than the other species, up to 18 m and over 100 metric tons (Kenney 2002). The distinguishing features of right whales include a stocky body, generally black coloration (although some individuals have white patches on their undersides), lack of a dorsal fin, large head (about ¼ of the body length), strongly bowed margin of the lower lip, and callosities on the head region (NMFS 2006).

The North Pacific right whale (*Eubalaena japonica*) is closely related to the right whales that inhabit the North Atlantic and the Southern Hemisphere. Genetic data now provide unequivocal support to distinguish three right whale lineages as separate phylogenetic species (Rosenbaum et al. 2000): (1) the North Atlantic right whale (*Eubalaena glacialis*) ranging in the North Atlantic Ocean from latitudes 60°N to 20°N; (2) the North Pacific right whale (*Eubalaena japonica*), ranging in the North Pacific Ocean from latitudes 70°N to 20°N; and (3) the southern right whale (*Eubalaena australis*), historically ranging throughout the southern hemisphere's oceans.

In both the northern and southern hemisphere, females give birth to their first calf at an average age of nine years (Best et al. 1998; Hamilton et al. 1998). The gestation period ranges from 357 to 396 days in southern right whales (Best 1994), and it is likely to be similar in the northern species. At birth, calves from the southern hemisphere are 5.5–6.0 meters in length (Best 1994). Little is currently known about the age of maturity, the timing of reproduction, or the rate of reproduction for North Pacific right whales. There have been very few confirmed sightings of calves in the eastern North Pacific this century. Calves have been reported in the western North Pacific (Omura 1986; Brownell et al. 2001), but calculation of meaningful reproduction rates remains impracticable. Right whales elsewhere in the world are known to calve every three to four years on average (NMFS 2006). Very little is known about natural mortality in this species, though killer whales and large sharks are potential predators, particularly on calves and juveniles (Kenney 2002). There are also few data on the longevity of right whales. Some evidence suggests that females can live to at least age 70, but recent research on bowhead whales suggests that they may live even longer (Kenney 2002).

Right whales are skimmers; they feed by continuously filtering prey through their baleen while moving, mouth agape, through a patch of zooplankton (NOAA NMFS 2006). The few existing records of right whale feeding habits indicate that right whales feed almost entirely on copepods (Omura 1958, Omura et al. 1969, IWC 1986, Omura 1986), but small quantities of euphasid larvae have also been found in North Pacific right whale stomach contents (Omura 1958).

[7] General Biology section largely drawn from National Marine Fisheries Service. 2006. Review of the Status of the Right Whales in the North Atlantic and North Pacific Oceans. 62 pp.

Range, migratory behavior, and stock structure

The historical ranges of right whales in the North Pacific were much more extensive than they are today. Right whales occurred from Japan and northern Mexico north to the Sea of Okhotsk, Bering Sea, and Gulf of Alaska (Kenney 2002). Formerly abundant across much of the North Pacific in summer, mainly north of 40°N, the North Pacific right whale is now regularly seen only in the Okhotsk Sea and the southeastern Bering Sea, with occasional sightings along the east coast of Japan, off the Bonin Islands, and in the Gulf of Alaska.

Some evidence suggests that there are at least two stocks (western and eastern) of right whales in the North Pacific, though there is disagreement regarding the number and boundaries of right whale stocks in the North Pacific (Brownell et al. 2001). Nevertheless, populations on the Asian and American sides of the Pacific are regarded as discrete (Brownell et al. 2001). In the eastern North Pacific, North Pacific right whales are now only regularly seen in the southeastern Bering Sea. Sightings off Hawaii (e.g., Herman et al. 1980, Rowntree et al. 1980, Salden and Mickelson 1999), Washington (e.g., Rowlett et al. 1994), California (e.g., Scarff 1986, 1991; Carretta et al. 1994, Woodhouse and Strickley 1982) and Mexico (e.g., Rice and Fiscus 1968, Gendron et al. 1999) are relatively rare, and there is no evidence that the western coasts of the United States and Mexico were ever highly frequented habitat for this species (Brownell et al. 2001).

Habitat use

In general, right whale feeding takes place in the spring, summer, and fall months in higher latitude feeding grounds, while calving tends to occur in the winter months in lower latitudes (Kenney 2002). Little is known about habitat use by modern North Pacific right whales, but it appears that fewer regions are utilized by North Pacific right whales today compared to whales in the 19th and 20th centuries (Brownell et al. 2001, Clapham et al. 2004). Recent data from acoustic recorders and surveys suggest that eastern stock of North Pacific right whales primarily utilize habitat in the southeastern Bering Sea from May through December (Allen and Angliss 2010). Although survey effort in the Gulf of Alaska is lower, it seems that North Pacific right whales utilized this area less than the southeastern Bering Sea (Allen and Angliss 2010). There is clearly some migration northward in summer and southward in winter (Clapham et al. 2004), but the location of the wintering grounds is unknown. The rarity of coastal records in winter, either in historical or recent times, suggest that their breeding grounds may have been offshore (Clapham et al. 2004), but no North Pacific right whale calving grounds have ever been discovered (Kenney 2002).

Critical habitat

Critical habitat for the North Pacific right whale was originally designated when the Atlantic and Pacific stocks were grouped together as northern right whales (NOAA, 2006). This critical habitat included two areas off Alaska, one in the Bering Sea and the second in the Gulf of Alaska (Figure 7). After it was determined that the North Pacific right whale is a separate species from the North Atlantic Right whale, the areas above were listed as critical habitat for the North Pacific right whale, effective May 8, 2008 (NOAA, 2008b).

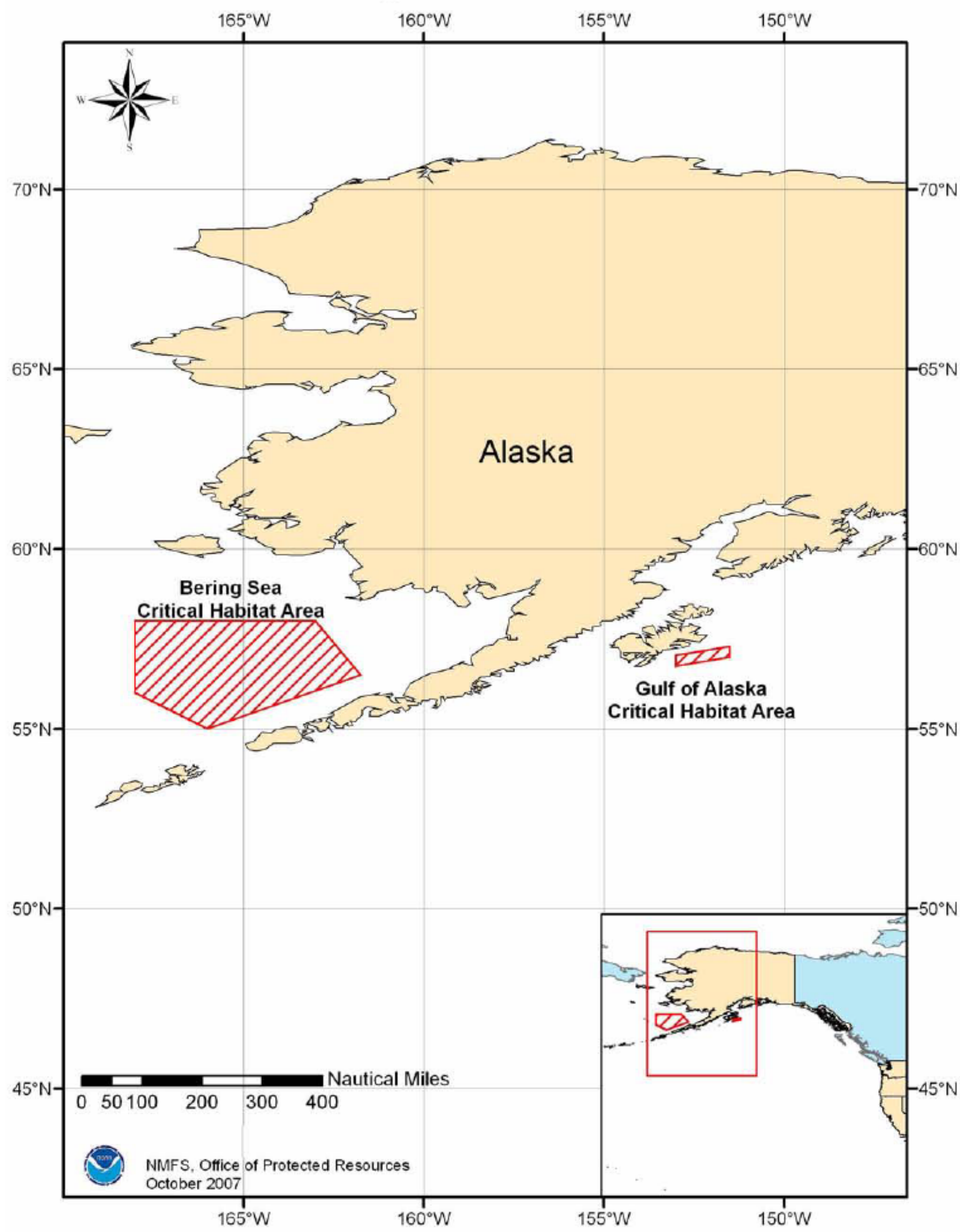


Figure 7: North Pacific Right Whale Critical Habitat (NMFS, 2006)

Status

The "northern right whale" was originally listed as endangered under the Endangered Species Conservation Act, the precursor to the ESA, in June 1970. In 1973 the "northern right whale" was listed as endangered under the ESA and depleted under the MMPA. In 2008, NMFS listed the endangered northern right whale (*Eubalaena spp.*) as two separate endangered species—North Pacific right whale (*E. japonica*) and North Atlantic right whale (*E. glacialis*) (NOAA 2008a). A Recovery Plan for the northern right whale, including both the North Atlantic and North Pacific right whales, was issued in 1991 (NMFS 1991). NMFS revised the plan in 2005 for the North Atlantic right whale. A separate Recovery Plan is being developed for the North Pacific right whale population.

Abundance and trend

Based on sighting data, Wada (1973) estimated a total population of 100–200 in the North Pacific. Brownell et al. (2001) suggested from a review of sighting records that the abundance of this species in the western North Pacific was likely in the "low hundreds." Rice (1974) stated that only a few individuals remained in the eastern North Pacific stock, and that for all practical purposes, the stock was extinct because no sightings of a mature female with a calf had been confirmed since 1900. Although there were no confirmed sightings of calves in this region in the 20th century, there have been three thus far in the 21st (Waite *et al.* 2003, Wade *et al.* 2006), which invalidates the view that the stock is extinct. A reliable estimate of abundance for the North Pacific right whale is currently not available, and consequently, there are no data on trends in abundance for either the eastern or western population (Allen and Angliss 2010). However, it is apparent that the population abundance of the eastern stock is very low. For example, of the 13 individual animals photographed during aerial surveys in 1998, 1999, and 2000, 2 have been re-photographed (LeDuc et al. 2001). This photographic recapture rate is consistent with a very small population size. This conclusion is supported by a preliminary genotype-based comparison of the 17 individuals biopsied in the Bering Sea in the summer of 2004, which also revealed at least 4 matches to animals biopsied in previous years (Wade et al. 2006). Recently, Wade et al. (2011) used photographic and genotype data to calculate the first mark-recapture estimates of abundance for right whales in the Bering Sea and Aleutian Islands. The estimates were very similar. Abundance was estimated to be 31 (95% CL 23-54) and 28 (95% CL 24-42) for the photographic and genotyping methods, respectively (Wade et al 2011). Wade et al. (2011) also estimated that the population contains eight females (95% CL 7-18) and 20 males (95% CL 17-37). It is probable that these estimates relate specifically to a subpopulation with strong site fidelity to the Bering Sea. However, the rarity of right whale sightings elsewhere make it very unlikely that the eastern North Pacific population is much larger than the estimates suggested by Wade et al. (2011).

The basic life history parameters and census data, including population abundance, growth rate, age structure, breeding ages, and distribution, remain undetermined for the North Pacific right whale (NOAA NMFS 2006). These data are necessary to perform quantitative population analyses or to develop surrogate models to evaluate the risk of extinction. However, there are a number of factors that put North Pacific right whales at considerable risk of extinction. These include, but are not limited to, the following: (1) life history characteristics, such as slow growth rate, long calving intervals, and longevity; (2) distorted age, size or stage structure of the population, and reduced reproductive success; (3) strong depensatory or Allee effects; (4) habitat specificity or site fidelity; and (5) habitat sensitivity (NOAA NMFS 2006). Due to insufficient information, it is recommended that the default cetacean maximum net productivity rate (RMAX) of 4% be employed for this stock (Wade and Angliss 1997). However, given the small apparent size and low observed calving rate of this population, this rate may be unrealistically high (Allen and Angliss 2010).

Threats (from Recovery Plan or listing documents)

Ship collisions and fishing gear entanglements are the most common anthropogenic causes of mortality in western North Atlantic right whales, judging from observations of stranded animals (NMFS 2005). Other potential threats identified in the North Atlantic right whale Recovery Plan are habitat degradation, noise, contaminants, underwater bombing activities, climate and ecosystem change, and commercial exploitation (NMFS 2005). A separate Recovery Plan for North Pacific Right whales is currently being developed. It is likely that the North Pacific right whales faces similar threats as the North Atlantic right whales, but since these whales are so rarely observed, the extent to which these whales are impacted by the above threats is unknown.

Fishery impacts

Fisheries may potentially impact North Pacific right whales through several mechanisms, including vessel collisions, physical disturbance, acoustic disturbance, entanglement in nets or lines, pollution from exhaust or spills, and direct or indirect reduction of prey. Ship collisions and fishing gear entanglements are the most common anthropogenic causes of mortality in western North Atlantic right whales, judging from observations of stranded animals (NMFS 2005). However, entanglements of North Pacific right whales in fishing gear appear to be uncommon. Only one case of entanglement (in gillnet) is known from the western North Pacific (Brownell et al. 2001), though the occurrence of right whales near pot fisheries in the Bering Sea indicates a potential for interactions. Given the low population size of the eastern North Pacific right whale stock, the impact of even low levels of interactions could be significant.

Impacts, all fisheries

California, Oregon, Washington – There is no evidence that the western coast of the United States was ever highly frequented habitat by North Pacific right whales, and there have also been no reported entanglements of these whales in fishing gear off these states (Brownell et al. 2001).

Mexico, Central America – There is no evidence that the western coasts of Mexico and Central America were ever highly frequented habitat by North Pacific right whales, and there have also been no reported entanglements of North Pacific Right whales in fishing gear off these areas (Brownell et al. 2001).

Alaska and Hawaii – There is no evidence that Hawaii is highly frequented habitat by North Pacific right whales, and there have also been no reported entanglements of North Pacific Right whales in fishing gear off the Hawaiian islands (Brownell et al. 2001). In contrast, there is a potential of impact with fisheries in Alaska. The majority of recent sightings of North Pacific right whales have been reported in the southeastern Bering Sea, with occasional sightings in the Gulf of Alaska. In fact, the designated critical habitat for this population includes two areas off

Alaska—one in the Bering Sea and the second in the Gulf of Alaska (Figure 7). Although the only observed entanglement of a North Pacific right whale was an individual from the western population entangled in gillnet on the Pacific coast of Lopatka, Kamchatka (Brownell et al. 2001), the occurrence of right whales near pot fisheries in the Bering Sea indicates a potential for interactions.

Impacts, WCGF fisheries

A very limited degree of overlap occurs between the WCGF fisheries regions and current North Pacific right whale distribution, so there is a very small potential for impacts due to ship strikes or entanglement. There were no recorded fishery interactions with North Pacific right whales from 2002–2009 reported by the A-SHOP or WCGOP observer programs (Jannot et al. 2011). Only one case of a North Pacific right whale entanglement is known from the western North Pacific, and it was attributed to a gillnet (Brownell et al. 2001). However, ship strikes and entanglements are common causes of mortality for North Atlantic right whales, so a small risk of ship strike and/or entanglement from West Coast commercial groundfish fishery activities can be reasonably assumed in the rare instances when North Atlantic right whales transit off the coasts of Washington, Oregon, and California.

Habitat and trophic effects

WCGF fisheries target relatively large, commercially valuable fish species, including rockfish, hake, and various mid-water and bottom fish (see Chapter 2). North Pacific right whales feed almost exclusively on copepods but can also consume small quantities of euphasid larvae. These primary prey species of North Pacific right whales are not impacted by the WCGF fisheries to any significant extent. Indirect trophic effects of the WCGF fisheries are also expected to be minor. In the case of intensive commercial fisheries that target larger species, it may be possible to alter the ecosystem structure in a manner that causes an increase in the abundance of other species that feed on zooplankton, particularly small fishes with lower economic value (Kenney 2002). This could potentially impact North Pacific right whales by increasing competition for food resources. However, since North Pacific right whales appear to feed in higher latitudes, this scenario, if it did occur, would not likely impact the feeding grounds of these whales.

Impact of WCGF fisheries on population growth rate

Due to the paucity of data on population abundance and reproductive rates combined with the rarity of observing North Pacific right whales in the WCGF fisheries regions, it is not possible to quantify an estimated impact of WCGF on population growth rate. However, based on the lack of any observed interactions and the very limited overlap between the species' range and the WCGF fisheries, current impacts from these fisheries on the species appear to be negligible.

*Blue whale (*Balaenoptera musculus*)*

General biology[8]

The blue whale is one of the rorquals, the family that also includes the humpback whale, fin whale, Bryde's whale, sei whale, and the minke whale. It is the largest animal ever known to live on earth, with some adults in the Antarctic reaching a body length of 33 meters. Blue whales in the Northern Hemisphere are generally smaller than those in the Southern Hemisphere, averaging 75 to 80 feet (23–24 m). Its body is long and slender with a small falcate dorsal fin located about three-fourths of the way back on the body. Blue whales are blue-gray in color with variable lighter gray mottling. In colder waters, these whales acquire diatoms that give their ventral surface a yellowish-green caste. Blue whales reach sexual maturity between the ages of 6–10 years, and calves are born at intervals of 2 to 3 years following a 12-month gestation period (Mizroch et al., 1984). Longevity is estimated to be 80–90 years. Blue whales feed almost exclusively on euphausiids by lunge feeding in large prey patches.

Range, migratory behavior, and stock structure

Blue whales are found in all oceans of the world. They inhabit and feed in both coastal and pelagic environments. Much of the population migrates to tropical-to-temperate waters in the winter months, presumably for mating and calving. While feeding has been observed at all latitudes, poleward movements in the spring allow the whales to take advantage of high zooplankton abundance in the summer months.

Within the species, three subspecies have been designated: *B.m. musculus* in the Northern Hemisphere, *B.m. intermedia* in the Southern Ocean, and *B.m. brevicauda*, the pygmy blue whale found in the subantarctic Indian Ocean and southwestern Pacific Ocean. In the North Pacific, the International Whaling Commission only recognizes one management stock (Donovan 1991), but it is thought that this ocean may include as many as five stocks (Reeves et al. 1998). Two distinct call types are produced in the North Pacific, termed the northeastern call type and the northwestern call type. It has been proposed that these call types represent two distinct populations with some degree of geographic overlap (Stafford et al. 2001). The eastern North Pacific Stock includes animals found from the northern Gulf of Alaska to the eastern tropical Pacific and is consistent with both the distribution of the northeastern call and the known range of photo identified individuals (Carretta et al. 2009).

The West Coast of the U.S. is one of the most important feeding grounds for the eastern North Pacific Stock of blue whales. The Gulf of Alaska and central North Pacific are also summer feeding grounds. Migration south to the high productivity areas off Baja California, the Gulf of California, and the Costa Rican dome is undertaken by most of this stock in the winter and spring. These destinations are areas of high productivity, and observations of feeding on them are not uncommon, so it is assumed that blue whales feed year-round.

[8] Unless otherwise noted, all material in this section was drawn from Reeves et al. (1998)

Habitat use

In fall and spring, blue whales can be found in the Gulf of California, Mexico and south to the offshore waters of Central America. By April and May, they migrate north to the West Coast of North America, where a large population is found in California waters (Figure 8). The presence and movements of blue whales off the coast of California is correlated with aggregations of their prey—*Euphasia pacifica* and *Thysanoessa spinfera* (Mate et al., 1999). In recent years, blue whales have shifted to a broader geographic distribution, including areas off British Columbia and in the Gulf of Alaska where they were common during commercial whaling, and this may be due to changes in prey driven by oceanographic conditions (Calambokidis et al. 2009, Barlow 2010).

Diving behavior of blue whales varies widely both regionally and temporally, but consistent feeding depths of 250–300 meters have been reported (Calambokidis et al. 2008).

Critical habitat

Critical habitat has not been identified for this species.

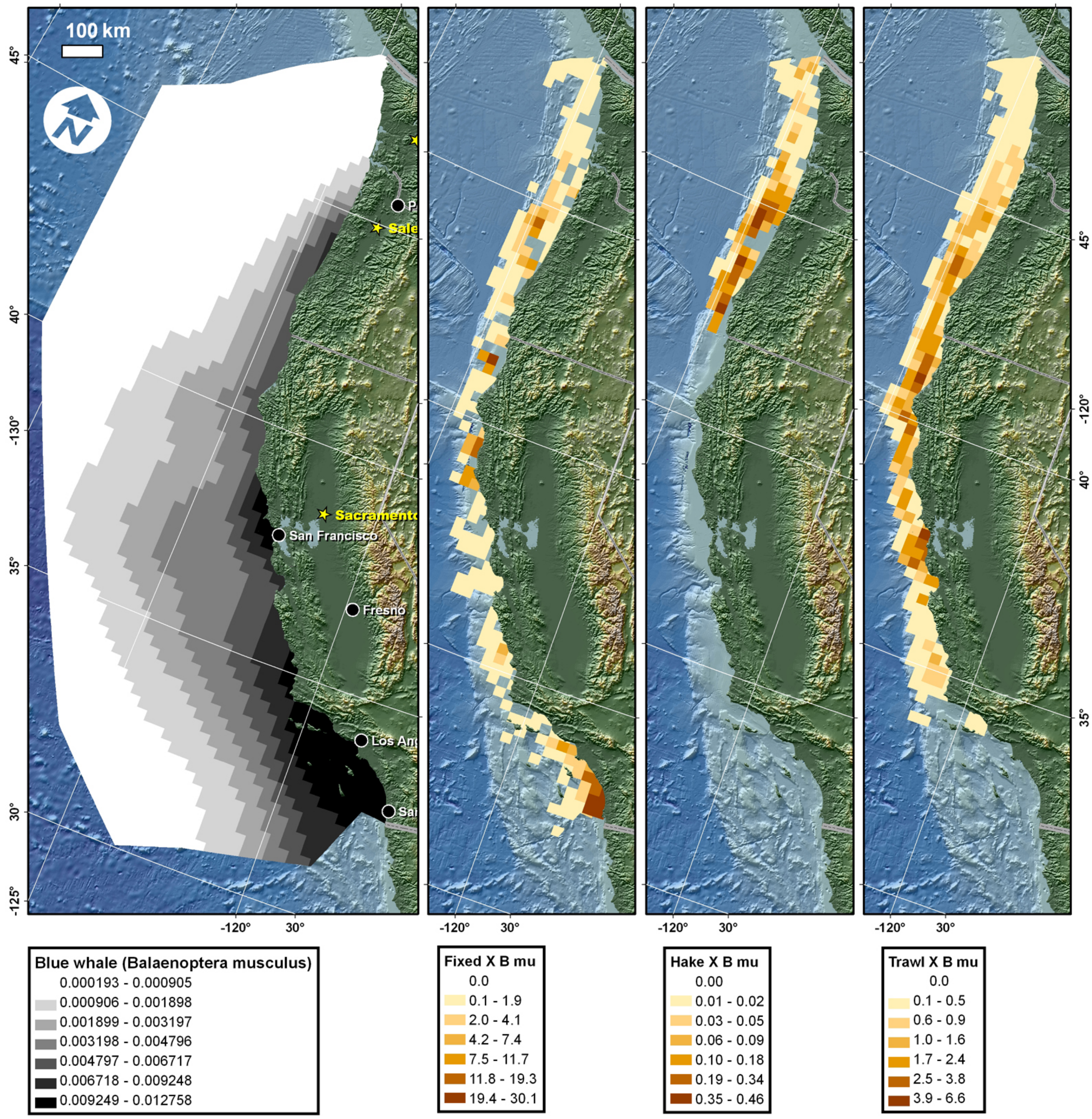


Figure 8: Left panel: Mean predicted blue whale density (number of animals/km^2), based on surveys conducted from June through November, from 1991 – 2005 (data from Barlow et al. 2009). Ship-based cetacean and ecosystem assessment surveys of blue whale sighting locations were extrapolated to a regular grid (25 km resolution) for each year and were smoothed with geospatial methods to obtain a continuous grid of density estimates for the California Current Ecosystem. Right panels: Overlap indices with three fishery sectors: fixed gear, hake trawl, and bottom trawl. Indices are in units of animal hours/km^2. See Appendix B for details.

Status

Blue whales were listed as endangered under the ESA in 1970. A Recovery Plan was finalized for this species in 1998 (Reeves et al. 1998). The eastern North Pacific stock is considered a "depleted" and "strategic" stock under the MMPA.

Abundance and trend

The size of the feeding stock of blue whales off the U.S. West Coast was estimated recently by both line transect and mark-recapture methods. Line transect ship surveys off of California, Oregon, and Washington produced estimates of 721 (CV=0.27) blue whales in 2005 and 442 (CV=0.25) in 2008 (Barlow 2010). Mean and minimum abundances were based on pooled results of the 2005 (Forney 2007) and 2008 surveys (Barlow 2010) and were estimated to be 565 (CV=0.18) and 485 respectively (Barlow 2010). Calambokidis et al. (2007) used photographic mark- recapture to estimate population size for 2004–2006. Population size estimates were calculated separately for right side and left side photographs (3,568 [CV=0.41] and 2,117 [CV=0.34] respectively). The average of the mark-recapture estimates is 2,842 (CV= 0.41). Line transect estimates reflect the average density and abundance of blue whales in the study area during the summer and autumn surveys, while mark-recapture estimates provide an estimate of the total population size. Therefore, the best estimate of blue whale abundance for the eastern North Pacific stock is the average of mark-recapture estimates or 2,843 (CV=0.41) (Carretta et al. 2009).

Although the eastern North Pacific stock of blue whales is expected to have grown since 1966 when it was given protected status by the IWC, there is no evidence that the stock is currently growing. There is some indication the blue whale abundance increased from 1979/80 to 1991 and from 1991 to 1996 (Barlow 1994, Barlow 1997). This may have been the result of increased use of the California feeding areas as opposed to an increase in the stock as a whole. Estimates in 2005 and 2008 from line-transect surveys were lower than those in 1996, which may represent inter annual variability in the fraction of the population utilizing California waters during the summer and autumn (Calambokidis et al. 2007, Barlow 2010).

Threats (from Recovery Plan or listing documents)

Blue whales face a variety of threats, depending on the region in which they occur. Threats listed in the Recovery Plan for blue whales in the North Pacific include collisions with ships, disturbance from vessels, entrapment and entanglement in fishing gear, habitat degradation, and military operations in and around feeding areas (Reeves et al. 1998). Ship strikes were implicated in the deaths of five blue whales from 2003–2007, with four of these occurring in 2007 (NMFS SWR Stranding database). Between 1988 and 2007, 21 blue whale deaths were reported along the California coast. These strandings were spatially associated with shipping lanes, especially those associated with the Ports of Los Angeles and Long Beach, and were most common in the fall (Berman-Kowalewski et al. 2010).

Fishery impacts

Fisheries may potentially impact blue whales through several mechanisms, including vessel collisions, physical disturbance, acoustic disturbance, entanglement in nets or lines, pollution from exhaust or spills, and direct or indirect reduction of prey.

No definite evidence of blue whales being killed or injured in fishing gear in the North Pacific is available (Carretta et al. 2009). Fishermen report that large blue and fin whales usually swim through the nets without entangling and with very little damage to the net (Barlow et al., 1997).

Impacts, all fisheries

California, Oregon, Washington – There have been no reported entanglements of blue whales in fishing gear off the West Coast (SWR and NWR stranding network; Appendix C). Carretta et al. (2009) concluded that because there have been no mortalities due to the California gillnet fishery, the total fishery mortality rate is approaching zero mortality and serious injury rate. The annual incidental mortality and serious injury rate from ship strikes (primarily attributed to shipping, not fisheries) of 1.2 whales per year is less than the PBR of 2.0 whales per year for this stock (Carretta et al. 2009). This rate does not include unidentified large whales, and therefore may be an underestimate.

Mexico, Central America – Carretta et al. (2009) summarized information on fishery interactions in Mexico as follows:

> Drift gillnet fisheries for swordfish and sharks exist along the entire Pacific coast of Baja California, Mexico and may take animals from the same population. Quantitative data are available only for the Mexican swordfish drift gillnet fishery, which uses vessels, gear, and operational procedures similar to those in the U.S. drift gillnet fishery, although nets may be up to 4.5 km long (Holts and Sosa-Nishizaki 1998). The fleet increased from two vessels in 1986 to 31 vessels in 1993 (Holts and Sosa-Nishizaki 1998). The total number of sets in this fishery in 1992 can be estimated from data provided by these authors to be approximately 2,700, with an observed rate of marine mammal bycatch of 0.13 animals per set (10 marine mammals in 77 observed sets; Sosa-Nishizaki et al. 1993). This overall mortality rate is similar to that observed in California driftnet fisheries during 1990–95 (0.14 marine mammals per set; Julian and Beeson, 1998), but species-specific information is not available for the Mexican fisheries. Previous efforts to convert the Mexican swordfish driftnet fishery to a longline fishery have resulted in a mixed-fishery, with 20 vessels alternately using longlines or driftnets, 23 using driftnets only, 22 using longlines only, and seven with unknown gear type (Berdegué 2002).

Impacts, WCGF fisheries

The highest degree of spatial overlap with WCGF fisheries occurs with the fixed gear sector, with some local overlap index values exceeding 20 animal hours/km^2 near San Diego just north of Cape Mendocino (Figure 8). Overlap with the trawl sector is much lower, with a few overlap indices exceeding approximately 4 animal hours/km^2 near Cape Mendocino and off of the San Francisco Bay (Figure 8). Overlap with the hake sector was very limited, and was <0.5 animal hours/km^2 in all locations (Figure 8).

Despite some overlap with the fishery, over the period from 2002–2009, there were no observed fishery interactions with blue whales reported by the A-SHOP or WCGOP observer programs (Jannot et al. 2011). Note, however, that impacts in the low-coverage fixed gear components of the fisheries cannot be ruled out. Of the ship strikes reported by the SWR and NWR stranding programs, none could definitively be identified as being caused by the WCGF fishery. Most of the ship strikes are believed to be associated with large commercial shipping traffic (Berman-Kowaleski 2010).

Habitat and trophic effects

WCGF fisheries target relatively large, commercially valuable fish species, including rockfish, hake, and various mid-water and bottom fish (see Chapter 2 Description of the Fisheries). Blue whales feed primarily on euphausiids, which are not impacted by the WCGF fisheries to any significant extent (Appendix A). Indirect trophic effects of the WCGF fisheries are also expected to be minor and in fact may positively affect the abundance of krill through removal of predators (Appendix A).

Impact of WCGF fisheries on population growth rate

The fishery is not expected to have an impact on the growth rate of this population. There have been no observed entanglements in fishing gear off the West Coast, and the incidental mortality and serious injury rate from ship strikes (none of which have been associated with this fishery) of 1.2 whales per year is less than the potential biological removal of 2.0 whales per year for this stock (Carretta et al. 2009).

*Fin whale (*Balaenoptera physalus*)*

General biology

Fin whales are the second largest rorqual after the blue whale and are characterized by a long, streamlined body with a V-shaped head. All fin whales have an asymmetrical pigmentation patter that is easily recognizable on the head region. The whale's underside, right lip, and right baleen plate are yellow-white, while their main body, left lip, and left baleen plate are a fairly uniform grayish-blue color (Silber et al. 1994). In the Northern Hemisphere, female fin whale length is about 22.5 meters and 21 meters for males (Aguilar 2009). Sexual maturity is reached for both sexes from 5 to 15 years (Lockyer 1972). Conception occurs during the winter months in both hemispheres, gestation is 12-months (Mizroch et al. 1984), and weaning occurs from 6–11-months after birth (Aguilar 2009). Fin whales feed on both krill and small schooling fish and are capable of bursts of speed of up to 23 miles per hour.

Range, migratory behavior, and stock structure

Fin whales inhabit oceans of both the Northern and Southern Hemispheres and are found at a wide range of latitudes between 20–75° (Department of Navy 2008). Migration occurs seasonally from the Arctic and Antarctic feeding areas to lower latitude breeding and calving areas in the winter. These whales tend to migrate in the open ocean; therefore, migration routes and the location of wintering areas are difficult to determine (Perry et al. 1999).

Two stocks of fin whales are recognized by the International Whaling Commission in the North Pacific—the East China Sea and the rest of the North Pacific (Donovan 1991). Mizrock et al. (1984) cites evidence, including whaling records, of additional fin whale populations in the North Pacific. For management purposes, three stocks of fin whales are recognized in U.S. waters—Alaska (Northeast Pacific), California/Washington/Oregon, and Hawaii (Allen and Angliss 2010).

Migratory behavior of fin whales in the eastern North Pacific is complex (NMFS 2010). Depending on their age, reproductive state, or stock, whales can occur in any one season at many different latitudes. Movements can either be inshore or offshore. Some individuals remain at high latitudes through the winter (Berzin and Rovnin 1966). In the northern North Pacific and Bearing Sea, fin whale concentrations form along frontal boundaries, which correspond roughly to the 200 meter isobath (Nasu 1974). Recently, satellite tag data from animals tagged in California and Washington suggest a general association with the continental shelf (Schorr et al. 2010).

Habitat use

Little is know about the movement patterns and habitat preferences of fin whales in the northeastern Pacific. Concentrations of fin whales can be found off the southern and central California coast year-round (Barlow 1995; Forney et al. 1995) (Figure 9). Acoustic signals from fin whales are detected year-round off Northern California, Oregon, and Washington with a concentration of vocal activity between September and February (Moore et al. 1998). Recent photo identification studies suggest that a higher degree of site fidelity may exist for some subareas along the U.S. West Coast during the summer and fall (Falcone et al. 2011).

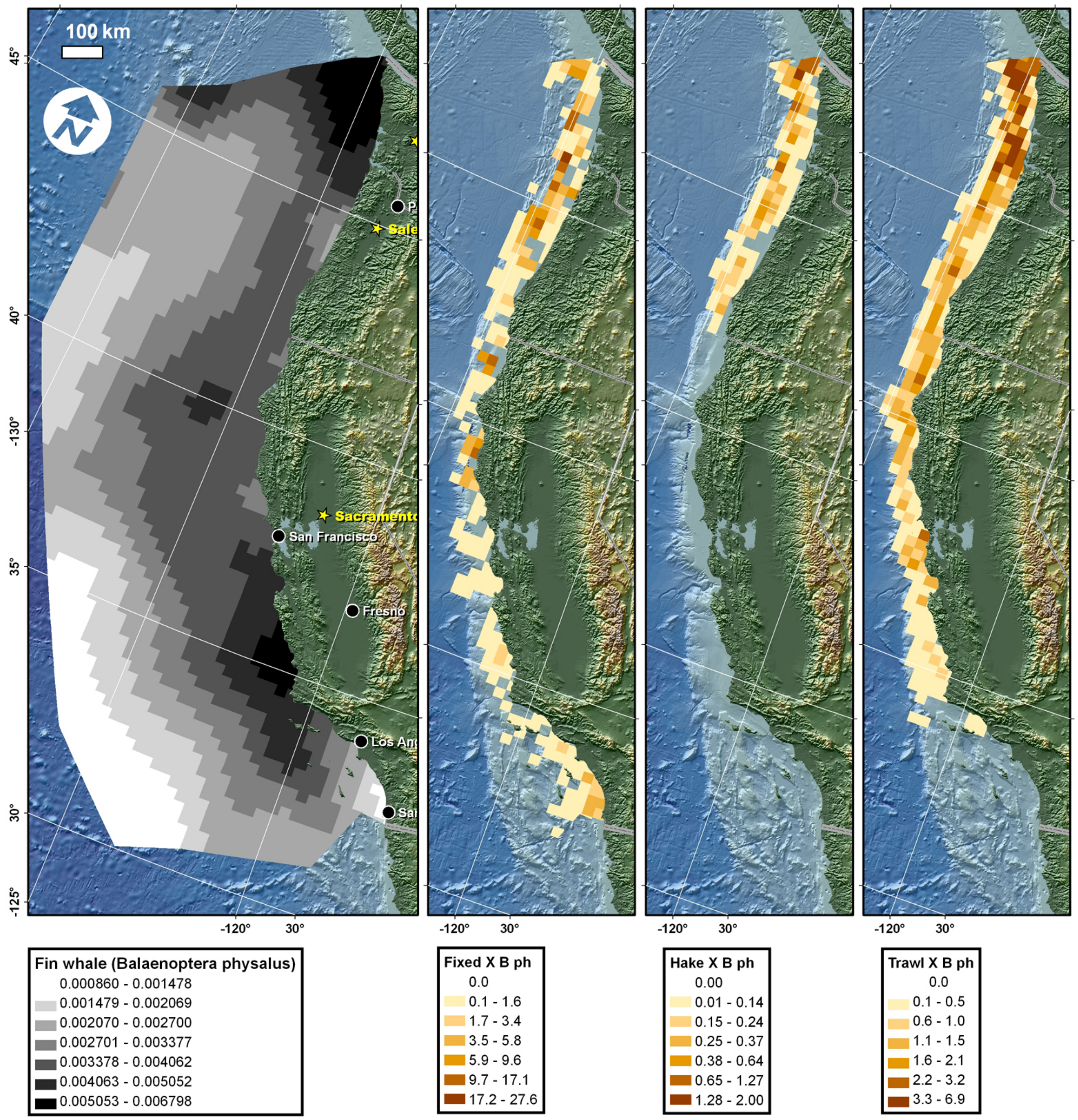


Figure 9: Left panel: Mean predicted fin whale density (number of animals/km^2), based on surveys conducted from June through November, from 1991 – 2005 (data from Barlow et al. 2009). Ship-based cetacean and ecosystem assessment surveys of humpback sighting locations were extrapolated to a regular grid (25 km resolution) for each year and were smoothed with geospatial methods to obtain a continuous grid of density estimates for the California Current Ecosystem. Right panels: Overlap indices with three fishery sectors: fixed gear, hake trawl, and bottom trawl. Indices are in units of animal hours/km^2. See Appendix B for details.

Critical habitat

Critical habitat has not been identified for this species.

Status

Fin whales were listed as endangered under the ESA in 1970. A Recovery Plan was finalized for this species in 2010 (NMFS 2010).

Abundance and trend (from Carretta et al. 2009)

The most recent abundance estimate for the California/Oregon/Washington area out to 300 nautical miles is 3,044 (CV=0.18), and is calculated as the geometric mean of the line transect estimate from summer/autumn ship surveys conducted in 2005 (Forney 2007) and 2008 (Barlow 2010). This is probably an underestimate because it excludes some fin whales that could not be identified in the field. Shipboard surveys in the summer and autumn of 1991, 1993, 1996, and 2001 produced estimates of 1,600–3,000 fin whales off California and 280–380 off Oregon and Washington (Barlow 2003). There is strong evidence of increasing fin whale abundance in the California/Oregon/Washington area from 1991-2008, and assuming no changes it is expected to continue to increase at the mean rate of about 3% a year (Moore and Barlow 2011).

Threats (from Recovery Plan or listing documents)

Fin whales face a variety of threats, depending on the region in which they occur. Threats listed in the Recovery Plan include fisheries interactions, ship noise, oil and gas activities, coastal development, military activities, ship strikes, disturbance from whale watching, contaminants and pollutants, disease, injury from marine debris, direct harvest, competition for resources, and loss of prey base due to climate and ecosystem change (NMFS 2010). In most cases, there is a medium to high level of uncertainty about these threats and their impact on fin whales in the North Pacific Ocean.

Fishery impacts

Fin whales may break through or carry away fishing gear, and whales carrying gear may die at a later time due to trailing gear, become debilitated or seriously injured, or have normal functions impaired, but with no evidence of the incident recorded (NMFS 2010). Off the eastern coasts of Canada and the United States, fin whales are occasionally killed or injured by inshore fishing gear, such as gillnets and lobster lines (Read 1994, Lien 1994, Waring et al. 1997). Very rarely, fin whales are entangled in inshore fishing gear in the North Pacific (Barlow et al. 1994, 1997).

Impacts, all fisheries

California, Oregon, Washington – The offshore drift gillnet fishery is the only fishery that is likely to directly affect fin whales from the California/Oregon/Washington stock, and one fin whale death has been observed since 1990 when NMFS began observing the fishery (Carretta et al. 2009). Based on the most recent observer data, the average fin whale bycatch in this fishery was approximately zero for the years 2002–2006 (Carretta et al. 2009). Carretta et al. (2009) also reported that a minimum of 1.6 deaths per year in this area due to ship strikes (unlikely to be fishery related).

Mexico, Central America – Carretta et al. (2010) summarized information on fishery interactions in Mexico as follows:

> Drift gillnet fisheries for swordfish and sharks exist along the entire Pacific coast of Baja California, Mexico and may take animals from the same population. Quantitative data are available only for the Mexican swordfish drift gillnet fishery, which uses vessels, gear, and operational procedures similar to those in the U.S. drift gillnet fishery, although nets may be up to 4.5 km long (Holts and Sosa-Nishizaki 1998). The fleet increased from two vessels in 1986 to 31 vessels in 1993 (Holts and Sosa-Nishizaki 1998). The total number of sets in this fishery in 1992 can be estimated from data provided by these authors to be approximately 2,700, with an observed rate of marine mammal bycatch of 0.13 animals per set (10 marine mammals in 77 observed sets; Sosa-Nishizaki et al. 1993). This overall mortality rate is similar to that observed in California driftnet fisheries during 1990‒95 (0.14 marine mammals per set; Julian and Beeson, 1998), but species-specific information is not available for the Mexican fisheries. Previous efforts to convert the Mexican swordfish driftnet fishery to a longline fishery have resulted in a mixed-fishery, with 20 vessels alternately using longlines or driftnets, 23 using driftnets only, 22 using longlines only, and seven with unknown gear type (Berdegué 2002).

Alaska and Hawaii –Allen and Angliss (2010) reported one incidental mortality of a fin whale in the Bearing Sea/Aleutian Islands pollock trawl fishery between 2002–2006. There have been no interactions with fin whales observed in the Hawaii-based longline fishery (Forney 2004). The impact of West Coast fisheries to the recovery of fin whale populations is considered low (NMFS 2010). In Hawaii, the ranking of the threat posed by the incidental capture of animals from the longline and pot/trap fisheries was also based on the assertion that there is a low uncertainty with regard to impacts to individual animals, and the impact to the recovery of fin whale populations due to these fishing practices is considered low (NMFS 2010).

Impacts, WCGF fisheries

The highest areas of spatial overlap with the fishery occur from the Columbia River mouth area northward, with overlap indices for the fixed gear sector of >20 animal hours/km 2 near the Columbia River mouth, and indices for the trawl sector >3 animal hours/km2 along the Washington Coast (Figure 9). The highest overlap index with the hake sector was < 2 animal hours/km2, off the northern Washington Coast (Figure 9).

Despite some overlap with the fishery, over the period from 2002–2009, there were no observed fishery interactions with fin whales reported by the A-SHOP or WCGOP observer programs (Jannot et al. 2011). Of the entanglements reported by the SWR and NWR stranding programs, none could be attributed to the WCGF. Note, however, that impacts in the low-coverage fixed gear components of the fisheries cannot be ruled out (see Introduction to Chapter 3).

Habitat and trophic effects

WCGF fisheries target relatively large, commercially valuable fish species, including rockfish, hake, and various mid-water and bottom fish (see Chapter 2). Fin whales feed on krill and small schooling fishes, such as anchovies and sardines, which are not impacted by the WCGF fisheries to any significant extent (Appendix A). Indirect trophic effects of the WCGF fisheries are also expected to be minor and in fact may positively affect the abundance of krill through removal of predators (Appendix A).

Impact of WCGF fisheries on population growth rate

There is some overlap between the WCGF fisheries and fin whale distribution, indicated the interactions are possible. However, there have been no observed interactions from 2002-2009, indicating that at least those components of the fishery with moderate to high observer coverage are not impacting the population's growth rate.

*Sperm whale (*Physter macrocephalus*)*

General biology

Sperm whales, the largest of the odontocetes (toothed whales) have a unique morphology, characterized by a massive head (25-35% of total body length) and a single asymmetrical blowhole on the left side of the head near the tip (Rice 1989). This species is dark gray with a white mouth and sometimes white patches on the belly, and has wrinkled appearing skin, a small rounded dorsal fin, and triangular shaped flukes (Gosho et al. 1984). Sperm whales have 20–26 conical teeth on each side of the lower jaw; teeth in the upper jaw do not erupt (Rice 1989). They are sexually dimorphic, with adult males attaining up to 16 m and 57 tons and females 12 m and 24 tons (Rice 1989). Sperm whales are believed to live approximately 60 years, with some females potentially living as long as 80 years (Whitehead 2003). Females are sexually mature at 9 years of age and produce a calf (4m, Ohsumi 1965) approximately every five years following a 14–16-month gestation period. Mating is believed to take place in April and May, and calving is thought to occur in July and August in the eastern North Pacific (Gregr et al. 2000). Most females occur in groups with other related individuals and maintain stable long-term groups. Young males disperse from their natal group between 4 and 21 years of age and are subsequently found in "bachelor schools" with similarly aged males. As males age, they begin to migrate to higher latitudes on their own. Once sexually mature in their late 20s, they occasionally return to the tropics to breed.

Sperm whales are noted for performing long (60–90 minute) and deep (1,000–3,000 m) dives (Rice 1989). These deep dives are related to their preferred prey, medium to large squid in pelagic areas, and to a lesser extent fishes, sharks and skates (Rice 1989, Gosho et al. 1984). In the eastern North Pacific, sperm whales have been found to primarily consume North Pacific giant squid (*Moroteuthis robusta*), but secondary preferences differed between males and females—females consumed ragfish (*Icostues spp.*) and males also consumed rock fish (*Sebastes spp.*) (Flinn et al., 2002).

Range, migratory behavior, and stock structure

Sperm whales occur in all oceans of the world, from tropical, temperate waters in the northern hemisphere to waters near the ice edge in the southern hemisphere. Females generally occur only in tropical regions, but they are also in temperate regions in the North Pacific. Adult males make seasonal pole-ward movements in summer, but the seasonal movements of females are less predictable. All sperm whales inhabit pelagic waters with productive oceanographic features (Jaquet 1996) or continental slope areas that tend to enhance or concentrate their primary cephalopod prey (Rice 1989, Smith and Whitehead 1993, Gannier and Praca 2007).

In the North Pacific, sperm whales are widespread with no defined breeding or feeding grounds. Discovery marks have shown widespread movement of individuals within the North Pacific basin (Omura and Ohsumi 1964, Ivashin and Rovnin 1967, Ohsumi and Masaki 1975, Wada 1980, Kasuya and Miyashita 1988 in Allen and Angliss 2010; Rice (AFSC-NMML, retired, pers. comm.)).

Sperm whales occur in all months of the year off California (Dohl et al. 1983, Barlow 1995, Forney et al. 1995), reaching their peak abundance from April to June and again from the end of August to mid-November (Rice 1974). Similarly, they are found off Washington and Oregon in all months except December to February (Green et al. 1992). Acoustic monitoring found that although sperm whales were year-round residents of the Gulf of Alaska, they were more common in summer than winter (Mellinger et al. 2004). These changes in monthly occurrence suggest seasonal movement patterns. However, satellite tagging of a small number of male sperm whales off Southeast Alaska showed that some tagged males moved south in the summer. While generally following the continental shelf slope, each whale that moved had unique movements (Andrews et al. 2011). Movements between southern California and British Columbia have been documented from discovery tags (Rice 1974). Based on catch records off BC, these appear to be segregation of area by sex with males occurring closer to shore than females (Gregr and Trites 2001).

The stock structure was summarized in the recent Recovery Plan (NMFS 2010):

> Stock structure in the North Pacific was a focus of intense discussion in the IWC Scientific Committee during the 1970s, a time when sperm whales were being heavily exploited by Japanese and Soviet pelagic whalers (IWC 1980). Masaki (1970) used tagging results, blood types, catch distributions, sighting patterns, and size compositions to establish the concept of three stocks: one west of 170°E (Asian stock), one between 180° and 160°W (mixed or Central stock), and one east of 150°W (American stock) (Tillman 1977). Ohsumi and Masaki (1977) emphasized that the “mixing” area in the central North Pacific was used primarily by males, and they proposed a two-stock scheme (east and west) for females, while retaining the previous three-stock scheme for males.
>
> Kasuya and Miyashita (1988) evaluated biological, bio-chemical, oceanographic, whaling, tagging, and sighting data, and concluded that there were three populations, but with boundaries different from those suggested by earlier authors. Their analysis suggested that the eastern North Pacific (or American) population is widely distributed north of 20°N, with breeding schools circulating between Mexican waters in the southeast, the historical whaling grounds centered around the Hawaiian Islands, the Alaskan Gyre, and waters on the south side of the Aleutian Chain. The boundaries for this population are approximately the Aleutians in the north, the North American coast in the east, and a line connecting 52°30’N, 175°E and 20°N, 160°W. Adult males of this population tend to be segregated longitudinally (toward the west) rather than latitudinally (toward the north) from the females and juveniles. For the western North Pacific population, Kasuya and Miyashita (1988) proposed northwestern and southwestern populations with the boundary shifting seasonally (Donovan 1991). The IWC recognizes 2 management units of sperm whales in the north Pacific (eastern and western although these boundaries have not been reviewed in recent years (Donovan 1991).

The U.S. recognizes three separate stocks under the MMPA: California-Oregon-Washington, Alaska, and Hawaii (Carretta et al. 2010, Allen and Angliss 2010). However, recent genetic analysis by Mesnick et al. 2011 indicates that the Alaska stock is actually comprised of whales (only males) from three genetically unique groups: California Current, Hawaii, and Eastern Tropical Pacific. A recent summary of Discovery mark data indicated widespread movement in the North Pacific (NMFS 2010):

> Discovery Mark data from the days of commercial whaling (260 recoveries with location data) show extensive movements of both males and females from U.S. and Canadian coastal waters into the Gulf of Alaska and Bering Sea and the coast of Japan Ground and Bonin Islands Ground (Omura and Ohsumi 1964; Ivashin and Rovnin 1967; Ohsumi and Masaki 1975; Wada 1980; Kasuya and Miyashita 1988, Mizroch, pers. comm. 2008). Rice (AFSC-NMML, retired, pers. comm. in Angliss and Allen 2009) marked 176 sperm whales during U.S. survey cruises from 1962–1970, mostly between 32° and 36°N off the California coast. Seven of those marked whales were observed in locations ranging from offshore California, Oregon, and British Columbia waters to the western Gulf of Alaska. A whale marked by Canadian researchers moved from near Vancouver Island, British Columbia to the Aleutian Islands near Adak. A whale marked by Japanese researchers moved from the Bering Sea just north of the Aleutians to waters off Vancouver Island, British Columbia (Mizroch pers. comm. 2009). Based on these data, there appear to be movements along the U.S. West Coast into the Gulf of Alaska and Bering Sea/Aleutian Islands region.

Satellite tag deployments on males by Andrews et al. (2011) off southeast Alaska show that the boundaries between Alaska and California-Oregon-Washington and Eastern Tropical Pacific are crossed.

Habitat use

Sperm whales generally inhabit deep pelagic areas or continental slopes, and this is where they are also at highest densities off the U.S. West Coast (Figure **10**). Sperm whales are widely distributed within deep, ice-free marine waters from the equator to the edges of polar pack ice (Rice 1989). Sperm whales are present in many warm-water areas throughout the year, and such areas may have discrete "resident" populations (Watkins *et al*. 1985; Gordon *et al.* 1998; Drout 2003; Jaquet *et al.* 2003; Engelhaupt 2004). While their aggregate distribution is certainly influenced by the patchiness of global marine productivity (Jaquet and Whitehead 1996), no physical barriers, apart from land masses or shallow seas, appear to obstruct their dispersal (Berzin 1972; Jaquet 1996).

In the North Pacific Ocean, seven areas of sperm whale concentration were described based on 19th century whaling records: (l) the Panama, Galapagos, and Offshore grounds in the eastern tropical Pacific; (2) the "On-the-Line Ground," an almost continuous equatorial belt extending a few degrees north and south of the Equator in the central Pacific; (3) the Hawaiian Ground centered between approximately 20°N and 35°N; (4) areas off Baja California and mainland Mexico; (5) the Japan Ground (28–35°N, 150–179°E); (6) the Coast of Japan Ground (34–40°N, 142–149°E); and (7) the Bonin Islands Ground southeast of southern Japan (Townsend 1935).

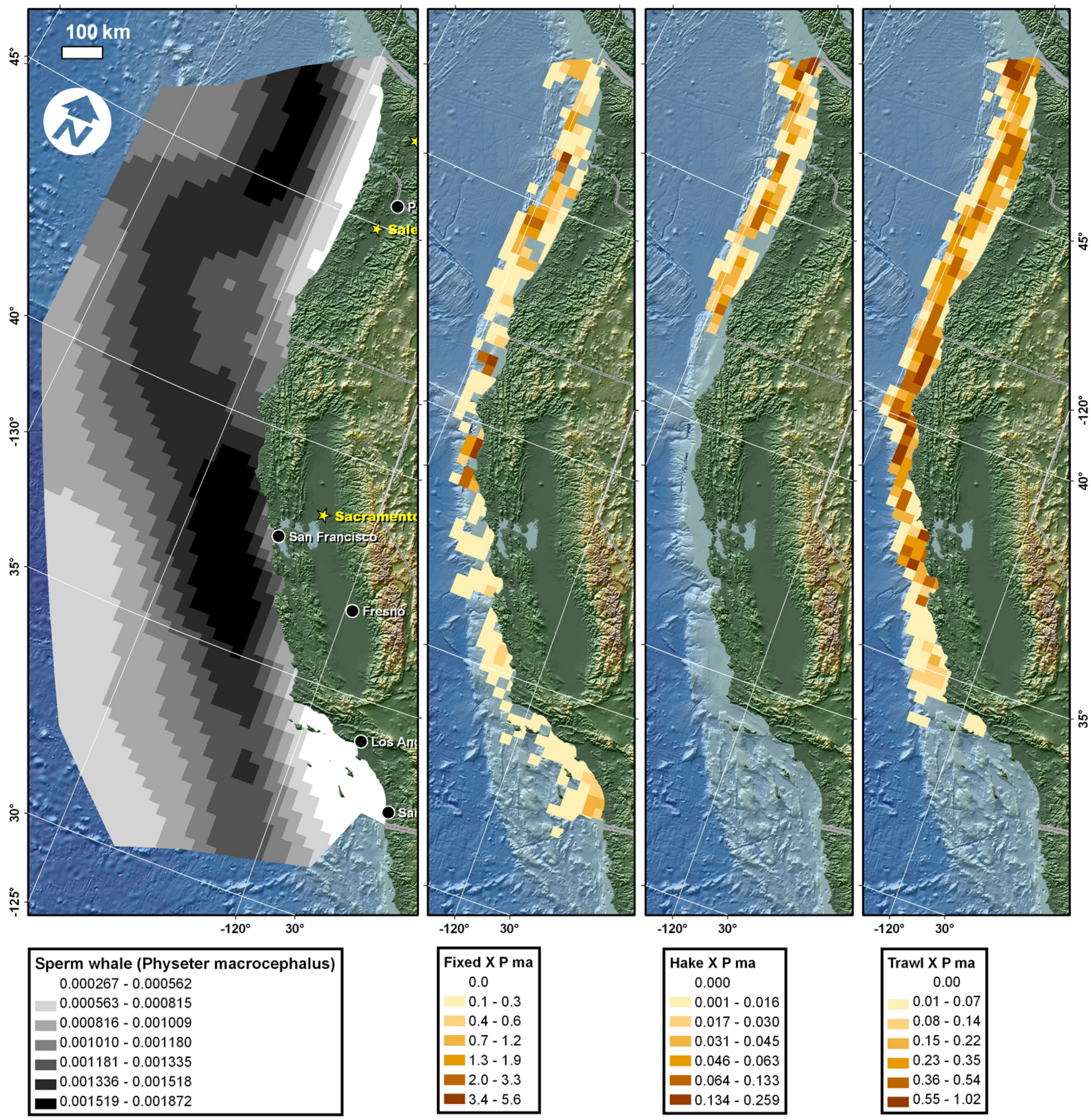


Figure 10: Left panel: Mean predicted fin whale density (number of animals/km^2), based on surveys conducted from June through November, from 1991 – 2005 (data from Barlow et al. 2009). Ship-based cetacean and ecosystem assessment surveys of humpback sighting locations were extrapolated to a regular grid (25 km resolution) for each year and were smoothed with geospatial methods to obtain a continuous grid of density estimates for the California Current Ecosystem. Right panels: Overlap indices with three fishery sectors: fixed gear, hake trawl, and bottom trawl. Indices are in units of animal hours/km^2. See Appendix B for details.

Sperm whales, including females and young males, were abundant on the whaling grounds up to 200 miles offshore from Vancouver Island and the Queen Charlotte Islands, British Columbia from spring through fall (Pike and MacAskie 1969). Although Townsend's (1935) charts show little evidence of sperm whales in the Gulf of Alaska and around the Aleutians, modern shore and pelagic whalers took adult males regularly in summer in deep offshore waters of the eastern Aleutians and Kodiak Island (Reeves *et al.* 1985). Large concentrations of breeding schools were reported by modern pelagic whalers along a line from 38°N, 142°W to 45°N, 135°W, thence northwestward to 50°N, 138°W and westward to 52°N, 148°W (Berzin 1972). The largest concentrations were centered around 50°N, 138°W and in a strip from 42°N, 140°W to 50°N, 154°W. Large numbers of females were observed along 41°N latitude (Berzin 1972).

Sperm whale distributions are presumably influenced by oceanographic features that themselves influence prey concentrations. In several ocean basins, sperm whales aggregate near frontal features (Biggs et al. 2000, Davis et al. 2002, Waring et al. 2001, Hamazaki 2002, Gannier and Praca 2007). In the Pacific Ocean, Jaquet (1996) noted that sperm whales were associated with primary productivity zones, particularly the Pacific equatorial zones.

Critical habitat

Critical habitat has not been identified for sperm whales.

Status

Sperm whales were listed in 1969 under the Endangered Species Conservation Act, and remained on the list of threatened and endangered species following passage of the Endangered Species Act in 1973 (35 FR 18319, 2 December 1970). A Recovery Plan was finalized for this species in 1991 (NMFS 1991). NMFS recently completed a new Recovery Plan for this species (see NMFS 2010).

Abundance and trend

The current world-wide estimate of the sperm whale population is 300,000–450,000 (Whitehead 2002), and the North Pacific population is estimated to be 152,000–226,000 (NMFS 2010). This abundance is thought to be less than 32% of the pre-exploitation population size (NMFS 2010). In the eastern North Pacific, a shipboard line-transect survey for sperm whales, using combined visual and acoustic methods, was conducted in a 7.8 million km^2 area between the West Coast of the continental United States and Hawaii in March–June 1997 (Barlow and Taylor 2005). The acoustic and sighting data were analyzed separately, yielding estimates of 32,100 (CV=0.36) and 26,300 (CV=0.81), respectively, and the two estimates were not significantly different (Barlow and Taylor 2005). Barlow (2006) estimated sperm whale abundance in the U.S. EEZ waters surrounding Hawaii as 6,900 (CV=0.81). Wade and Gerrodette (1993) estimated that there were 22,700 (CV=0.224) sperm whales in the eastern tropical Pacific. These whales are thought to belong to a different population from those off California, Oregon, Washington, and northward. The most recent (2008) estimate for the California-Oregon-Washington stock is 300 (CV=0.51) (Barlow 2010). However, two recent estimates from 2001 and 2005 were 2,593 and 3,140, respectively. The current population estimate, developed for this population using the 2005 and 2008 surveys, is 971 (CV=0.31). Although the 2008 estimate is sharply lower than the 2001 or 2005 estimates, it is not believed that the population has declined; rather, this change likely reflects inter-annual variability in the region (Carretta et al. 2010). There is no estimate of sperm whales in the Alaska stock (Allen and Angliss 2010) Only one estimate has been developed for Baja California, 1,640 (CV=0.33) (Barlow and Taylor 2005).

Threats (from Recovery Plan or listing documents)

Sperm whales are exposed to a variety of threats depending on the region in which they occur. Primary threats listed in the Recovery Plan include collisions with vessels, direct harvest, and possibly competition for resources, loss of prey base due to climate change, and disturbance from anthropogenic noise (NMFS 2010). Other potential (but likely low impact) threats include entanglement in fishing gear, habitat degradation, disturbance from vessels and tourism, contaminants and pollutants, disease, disturbance due to research, predation and natural mortality, and cable laying (NMFS 2010).

Fishery impacts

Fisheries interactions are a potential source of injury and mortality for many cetacean species, particularly those on the continental shelf or slope waters. In particular, entanglement in fishing gear (including nets and lines) is a significant source of injury or mortality for some species. Interactions of sperm whales with gillnets and long line fisheries have been documented in several regions, although impact level is estimated to be low (NMFS 2010)

The following information from the most recent Recovery Plan (NMFS 2010) summarizes the potential for sperm whale fishery interactions:

> The vulnerability of sperm whales to incidental capture in fishing gear, especially gillnets set in deep water for pelagic fish (*e.g.*, sharks, billfish, and tuna) and bottom-set longline gear, is well documented (Di Natale and Notarbartolo di Sciara 1994; Haase and Felix 1994; Felix *et al.* 1997; Hill *et al.* 1999; Straley *et al.* 2005; Warner *et al.* 2005). Sperm whales may break through or carry away fishing gear. Whales carrying gear may die at a later time due to trailing fishing gear, become debilitated or seriously injured, or have normal functions impaired, but with no evidence of the incident recorded. Sperm whales may also become entangled while attempting to depredate fish off fishing gear. Thus, it is possible that the increased strandings frequency in the Atlantic could be related to fishery bycatch (whales having drowned in gear) (Evans 1997). Direct action taken by fishermen to protect their catch and gear from depredation by sperm whales could result in serious injuries or mortality.
>
> Sperm whales may become entangled in fishing gear (recorded most often in demersal longline gear) while attempting to depredate fish off of the gear (Warner *et al.* 2005). Southern Pacific Ocean interactions involve demersal longline fisheries for Patagonian toothfish (*Dissostichus eleginoides*). There are records of depredation or possible depredation occurring in Chile (Oporto and Brieva 1994; Ashford *et al.* 1996; González 2001; González *et al.* 2001; Olivarría 2002; Hucke-Gaete *et al.* 2004). In Chile (Hucke-Gaete *et al.* 2004), aggressive competition between sperm and killer whales for a spot at

the hauling station of longliners were reported. Entanglements in longline fishing gear have been observed in Chile (Ashford *et al.* 1996). Although the magnitude of these interactions is infrequently documented, there are reports of sperm whales that have been shot by guns or harpoons and the use of explosives to keep animals away from fishing gear (González 2001). In addition, Haase and Felix (1994) recorded two instances in which sperm whales were killed after becoming trapped in tuna purse-seine nets off Ecuador. The ranking of the threat posed by the incidental capture of animals by these fishing practices to sperm whale recovery was listed under the global population/stock, reference G.1 (Table 1). Reports of fishermen shooting whales with guns and harpoons in the artisanal fishery off Southeast Chile represent potentially fatal threats provoked by frustration with reduced catches due to sperm whale depredation (González and Olivarría 2002).

Impacts, all fisheries

California, Oregon, Washington – The following information (Carretta et al. 2010) summarizes fishery interactions:

> The offshore drift gillnet fishery targeting swordfish and sharks off Oregon, California, and Baja California (Mexico) is a recognized threat to sperm whales. While the California/Oregon drift gillnet fishery killed/seriously injured several sperm whales in the 1990s, since the creation of a leatherback sea turtle (*Dermochelys coriacea*) conservation area was implemented in 2001 off central California and Oregon (66 FR 44549), no sperm whales have been observed taken in this fishery. One sperm whale stranded dead in 2004 with 5- to 6-inch mesh nylon netting found in its stomach and two sperm whales stranded dead in 2008 with a variety of netting in their stomachs (U.S. Department of Commerce 2009, J. Cordaro, NMFS-SWR, pers. comm., 2009). The fishery source of those nets is unknown, but is currently being analyzed to determine the type and source (country/area). Mean annual takes for these "unknown" fisheries are based on 2002–2006 data (Carretta and Chivers 2004; Carretta et al. 2005a, 2005b; Carretta and Enriquez 2006, 2007). This results in an average estimate of 0.2 (CV = not available) sperm whale deaths per year attributed to all fisheries. The threat posed by the drift gillnet fishery was ranked as low based on the assertion that there is a low uncertainty with regard to the extent of impact the fishing practice may have on sperm whales and that the severity of the threat to the overall population was low.

Mexico, Central America – The following information (Carretta et al. 2010) summarizes fishery interactions: "No estimates of mortality/serious injury are available for the Mexican drift gillnet fisheries (Carretta et al. 2009). Palacios and Gerrodette (1996) noted that sperm whales are at least occasionally killed in artisanal gillnet fisheries targeting sharks and large pelagic fishes off the Pacific coasts of northwestern South America, Central America, and Mexico."

Alaska – The following information (Allen and Angliss et al. 2010) summarizes fishery interactions:

> In the North Pacific, longline depredation is a localized phenomenon, occurring mainly in the central and eastern Gulf of Alaska, occasionally in the western Gulf of Alaska and

Aleutian Islands, and absent in the Bering Sea (Sigler et al. 2008). In this region, depredation occurs in December 2010 I-24 NMFS the sablefish (black cod) (*Anoplopoma fimbria*) and Pacific halibut fishery (*Hippoglossus stenolepis*) (Hill et al. 1999; Straley et al. 2005; Sigler et al. 2008). Investigations have been conducted to document rates of depredation, to understand how sperm whales manage to find vessels and remove fish from the gear, and to quantify the amount of prey removed and record the frequency of resulting mortality or serious injury due to entanglement. For instance, in 2006, the "Symposium on Fisheries Depredation by Killer and Sperm Whales: Behavioural Insights, Behavioural Solutions," was held in British Columbia. Reports of depredation were first noted in 1978, in the Gulf of Alaska, and from 1989–2003, 38 surveyed stations recorded sperm whale predation on longline catch (Angliss and Outlaw 2005). However, from 1998 to 2004, neither sperm whale presence nor depredation rate increased significantly (Sigler et al. 2008). In collaboration with fishermen, research using genetic, acoustic, and fishing behavior studies has been conducted in the Sitka area to gain insight into what may attract sperm whales to longlining activity (Sigler et al. 2003; Straley et al. 2005). Preliminary analyses found that during a typical encounter when sperm whales are present during the haul, about 3%–6% of the catch was estimated to be removed, but sometimes over 50% of the catch has been lost by individual fishermen. As the frequency of depredation events increases, there are growing concerns about the potential for sperm whale entanglements and the prospect of growing economic losses. In Alaska, there are reports of fishermen throwing seal bombs in the water and yelling at the whales when they depredate their gear.

Based on information documented from 1999–2003 (observer data), one sperm whale was observed with trailing gear from the Gulf of Alaska sablefish longline fishery; however, from 2001–2005, there have been no observed serious injuries or mortalities in federally observed Alaska fisheries (Angliss and Outlaw 2007). However, in 2006, there were three observed serious injuries in the Gulf of Alaska sablefish longline fishery, which extrapolates to 10 estimated serious injuries for that fishery for that year. Total estimated total annual takes is 2.01 (CV=0.49) animals (Angliss and Allen 2009).

The threat by North Pacific fishing practices in Alaska from the sablefish fishery to sperm whale recovery was ranked as low since only a small proportion of the population, when compared to the global population, depredates the sablefish fishery in Alaska. The severity and uncertainty of this threat are ranked as low. The average 5-year estimate within the Hawaiian Islands of annual mortality and serious injury is zero (between 1998–2002). Since 2001, the Hawaii-based long line fishery has undergone a series of regulatory changes, primarily to protect sea turtles, but the potential impacts of these regulatory changes on the rate of sperm whale interaction in unknown. The Hawaii-based longline fishery was ranked as low since few whales have interacted with these fisheries, and the severity and uncertainty of these interactions is low (the one animal that was observed caught in longline gear was apparently able to free itself and not considered seriously injured) (Forney 2004).

Hawaii – The following information (Carretta et al. 2010) summarizes fishery interactions: "One sperm whale has been reported entangled in a longline fishery near Hawaii (Carretta et al. 2006), but that animal freed itself and was not considered to be seriously injured (Forney 2004)."

Impacts, WCGF fisheries

Overlap indices between the sperm whale distribution and the fishery are generally lower than for other whales. For the fixed gear sector, the maximum values are < 6 animal hours/km^2 and occur in only a few places north of Cape Mendocino (Figure 10). Overlap indices for the trawl sector are fairly low and uniform from San Francisco to Cape Flattery, and are generally < 1 animal hours/km^2 (Figure 10). Overlap indices for the hake sector are all < 0.3 animal hours/km^2 (Figure 10).

Of the potential types of interactions—entanglement, catch depredation, and ship strikes—only one ship strike by a fishing vessel has been observed (with no serious injury or mortality) over the period from 2002–2009 (Jannot et al. 2011). Although three dead stranded sperm whales have been reported to have netting in their stomachs (U.S. Department of Commerce 2009, J. Cordaro, NMFS-SWR, pers. comm., 2009), it is unclear if the netting was associated with any of the WCGF fisheries or if mortalities were associated with the netting.

Habitat and trophic effects

WCGF fisheries target relatively large, commercially valuable fish species, including rockfish, hake, and various mid-water and bottom fish (see Chapter 2). Sperm whales feed primarily on squid in the north Pacific, but males have been documented to also consume rockfish (Flinn et al. 2002). Consequently, although overlap in target species and diet is limited, it is possible that competition for resources could occur with WGCF fisheries. Indirect trophic effects of the WCGF fisheries are also expected to be minor (Appendix A).

Impact of WCGF fisheries on population growth rate

Based on the information summarized above, we conclude that West Coast fisheries (including the WCGF fisheries) may be imposing some additional (non-natural) mortality on sperm whales. The number of takes per year may be higher than the estimated value 0.2 in California-Oregon-Washington. In addition, there is some overlap of individuals between the CA-OR-WA stock and the Alaska stock, so some of the interactions that occur in Alaska may also impact the CA-OR-WA stock and vice verse (Mesnick et al. 2011). Although the population is expected to have been recovering since cessation of whaling in 1980 (Whitehead 2002), the effects of unreported catches (Yaklokov 1994) and ongoing incidental ship strikes and gillnet mortalities (Carretta et al. 2010) remain somewhat uncertain. The only trend analysis for U.S. stocks was for the CA-OR-WA stock; although the most recent estimate was substantially lower than the two previous estimates, this was not thought to be a true expression of the population trend, given that the majority of this sperm whale stock inhabit areas near the EEZ boundary, and analysis of marked animals indicates widespread movement throughout the Pacific Basin. There has been no statistical analysis of trends in other U.S. sperm whale stocks or for the other areas of the North Pacific Ocean. Although precise estimates of the total sperm whale population in the North Pacific are lacking and available data are dated, the best estimate of the number of whales estimated to occur here (930,000; Rice 1989) is substantially higher than most other large cetaceans in this region, suggesting the species is unlikely to be severely impacted. Despite the paucity of specific data, we conclude that recent impacts from the WCGF fisheries are not likely to have a substantial impact on the population abundance or trend of sperm whales either locally or in the Pacific as a whole. The absence of any observed mortality of sperm whales from the WCGF fisheries, the low level of observed non-lethal interactions, and the general lack of any other anthropogenic sources of mortality, combined with the relatively large population size in the North Pacific and high degree of mobility in this population, indicates that the WCGF fisheries are unlikely to have a significant impact on the viability of this globally listed species.

*Southern Resident Killer whale (*Orcinus orca*)*

General biology[9]

Killer whales are the world's most widely distributed cetacean species, with solid black and white markings and a characteristic white or grey "saddle patch" located adjacent to the dorsal fin. Killer whale adults typically weigh 4–6 tons, with mature lengths of 4–6 m. In the Pacific Ocean, females bear their first calves at 10–12 years of age, reproduce until age 42–43, and may live to be more than 90 years old. Males typically have a shorter lifespan, potentially reaching up to 60 years of age. Calving intervals are from 3–5 years following an 18-month gestation period. Depending on the population ecotype, killer whales may feed on fish or marine mammals. Population structure is highly cohesive, with strong social structure extending across multiple generations (see Krahn et al. 2004 and references cited therein).

Range, migratory behavior, and stock structure

Three distinct ecoytypes of killer whales are found in the eastern Pacific: fish eating 'residents', marine mammal eating 'transients', and 'offshore' whales, whose diet is primarily fish. These ecotypes are distinct, with independent populations not inter-breeding. Recently, mitochondrial DNA has suggested that the three ecotypes have been separated for at least 150,000 years and should be considered separate killer whale species (Morin et al. 2010).

In the North Pacific, at least five populations of resident killer whales are recognized as utilizing portions of the U.S. coast: Northern Residents, Southern Residents, Prince William Sound Residents, Southeast Alaska Residents, and Western Alaska Residents (Krahn et al. 2004). Each of these populations is thought to be independent, with at most limited dispersal or inter-breeding occurring between populations.

The Southern Resident distinct population segment (DPS) ranges from central California to the Queen Charlotte Islands (British Columbia). The population is composed of three pods ('J', 'K', 'L'), each pod being an aggregation of matrilines (a matriline representing a female, and any offspring, spanning two or more generations). Relatively little information is known about the detailed migration routes or duration of migrations. Unlike other whales, killer whales do not have separate breeding and feeding grounds; migrations are thought to be driven by a search for prey (Krahn et al. 2004).

Globally, killer whales are generalist predators, but populations specialize on fish that are regionally abundant. These regionally important prey include herring in the north Atlantic (Similä et al. 1996), rays and elasmobranchs in New Zealand (Visser 1999), cod in the Antarctic (Pitman & Ensor 2003), and salmon in the northeast Pacific (Ford & Ellis 2006; Hanson et al. 2010).

[9] General biology summary largely drawn from Krahn et al. (2004), Wiles (2004), and NMFS (2008).

Habitat use

All three pods that form the Southern Resident population occur in inland Washington waters during summer months, with J pod occurring the most frequently (Table 10). Habitat use outside of summer months, or outside of inland Washington waters, is largely unknown. In winter months, J pod is still seen the most frequently. Sightings of K and L pods are less frequent in these months, and in recent years, both pods have been seen as far south as Monterey, California (Wiles 2004; Krahn et al. 2004, Table 1).

Table 10: Average number of days spent by Southern Resident killer whales in inland waters by month, 2003-2009 (Hanson & Emmons, unpublished).

Months	Jpod	Kpod	Lpod
January	2	6	3
February	5	1	1
March	5	1	1
April	10	0	0
May	25	3	1
June	24	11	13
July	24	18	16
August	18	16	17
September	19	16	18
October	13	9	11
November	13	6	5
December	8	10	1

Critical habitat

Critical habitat for the Southern Resident killer whale population has been identified (NMFS 2006; Fed Register, v. 71, no. 229, p. 69054-69070). This area includes the summer core area (San Juan Islands), in addition to the Puget Sound and Strait of Juan de Fuca regions (Figure 11).

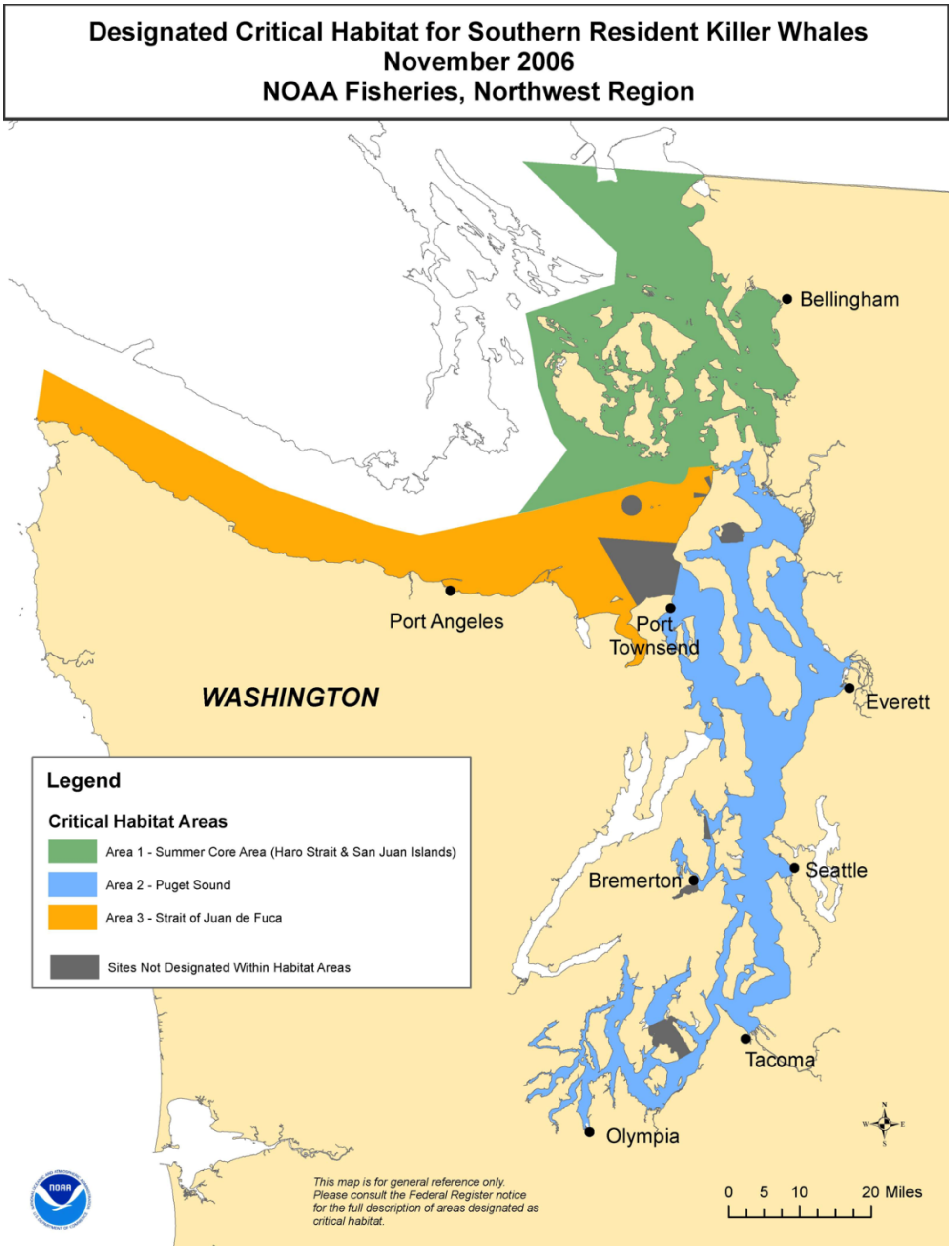


Figure 11: Critical habitat designation for Southern Resident killer whales. Reprinted from NMFS 2006.

Status

The Southern Resident population of killer whales was listed as endangered under the ESA in 2005 (NMFS 2005, 70 FR 69903). A Recovery Plan was finalized for this species in 2008 (NMFS, 2008), and a 5-year Status Review of the species was completed in May 2011 (NMFS 2011).

Abundance and trend

Prior to 1976, the Southern Resident DPS was subjected to a relatively large number (n = 47) of removals for marine parks. Nearly all of these captured animals were immature, and the 1971 population size was reduced to an estimated 67 individuals (Olesiuk et al. 1990). Photo-ID methods developed in the early 1970s have been used every year since, creating a detailed catalog of individual births, deaths, and reproductive performance.

As of 2011, the Southern Resident population has increased at a rate of 0.4% per year over the last several decades (NMFS 2011). While growth has been positive, it is less than the growth of the Northern Resident population over the same period, and less than the mean growth rate that is required for delisting (2.3% per year; NMFS 2008).

Threats (from Recovery Plan or listing documents)

NMFS has identified three primary threats to the viability of Southern Resident killer whales: reduced prey availability, contaminants in the food web, and direct or indirect disturbances from vessel interactions and sound (NMFS 2011). Because the current population size of Southern Residents is so small, this population is also more susceptible to risks of chance events. As the Southern Resident population is closed to breeding with other populations, an additional risk associated with small populations is lowered genetic diversity.

Fishery impacts

Fisheries may potentially impact killer whales through several mechanisms, including vessel collisions, physical disturbance, acoustic disturbance, entanglement in nets or lines, pollution from exhaust or spills, and direct or indirect reduction of prey (NMFS 2011).

It is extremely rare for killer whales to become entangled in fishing gear. Of all gear types, killer whales may most often be associated with longline fisheries, where they are known to remove fish caught on longline hooks (Visser 2000). Interactions between resident killer whales and gillnets were monitored in an expanded observer program in Washington State in 1993; during this period, killer whales were seen approaching gillnets, but no entanglements were reported (NMFS 2009, 75 FR 12498).

Impacts, all fisheries

California, Oregon, Washington – The total direct fishery induced mortality due to entanglements in gillnets or other gear has been zero since 1988 (Carretta et al. 2009). No serious injuries or mortalities have been observered or recorded in other fisheries within the species' range, such as Canadian gillnet fisheries.

Impacts, WCGF fisheries

There are no reported interactions between the WCGF and killer whales (Jannot et al. 2011). Because the fecundity and survival rates of the Southern Resident killer whales appear to respond to changes in the abundance of Chinook salmon (their primary prey), one mechanism by which the WCGF fisheries could impact the whales is through bycatch of Chinook salmon.

Chinook salmon bycatch in the WCGF fisheries has been summarized by the Northwest Regional Office and the West Coast Observer Program (Table 11). Since 2004, the methodology used to estimate bycatch has been consistent (Bellman et al. 2010). While Chinook salmon bycatch has decreased in both sectors of the fishery, the hake sector continues to represent the largest fraction of bycatch (over 90% of bycatch 2007–2009). Of the non-hake sector, the most bycatch occurs in the limited entry groundfish bottom trawl (Bellman et al. 2010; Bellman et al. 2011).

Table 11: Estimated Chinook bycatch for the hake and non-hake sectors of the groundfish fishery (Bellman et al. 2010; Bellman et al. 2011; Bellman & Hastie 2008; Hastie 2005; Heery et al. 2009; NMFS 2007). The non-hake component is further stratified by the limited entry groundfish bottom trawl. Totals are not available in all years due to unaccounted for mortality in other WCGF fishery sectors.

	Non-hake sector		**Hake sector**	**Total**
Year	LE groundfish trawl			
2004	2203		8751	N/A
2005	799		11916	N/A
2006	96		3975	N/A
2007	187		6186	6420
2008	344		3380	3769
2009	296		2712	3087

Of the total Chinook bycatch, it is likely that only a small portion overlaps with the Southern Resident prey base with respect to size. Many of the individuals included as bycatch are smaller than 60 cm (younger than 2 years old). In 2007, an estimated 45% of the coastwide Chinook bycatch was less than 60 cm (Jesse 2008). In 2008, the fraction was closer to 85% (Bellinger et al. 2009). In contrast, data collected from killer whale foraging events suggests that killer whales exhibit strong size-selectivity, preferring older and larger Chinook salmon (Ford & Ellis 2006; Hanson et al. 2010), particularly 4-5 year old salmon that are returning to natal streams to spawn.

Spatially, there may be only a small amount of overlap between stocks commonly found in Southern Resident killer whale diet and stocks included as bycatch in the WCGF fisheries. Chinook stocks that are included bycatch tend to be southern stocks, originating south of the Columbia River (Bellinger et al. 2009). Stocks originating from Puget Sound, British Columbia, and Alaska represent < 10% of total bycatch. These same northern stocks represent the largest contribution to Southern Resident diet, based on feeding events in inland waters (Hanson et al. 2010).

The Fishery Regulation Assessment Model (FRAM; http://www.pcouncil.org/salmon/background/document-library/) has been used as a tool to assess the overall impact of fishing on Southern Resident killer whales. In coastal waters, the average ratios of Chinook biomass to Chinook required by Southern Resident killer whales are higher than similar ratios in inland waters; in coastal waters, the mean ratio ranges from 10-35x (PS Chinook RMP; A. Agness, unpublished).

Output from the FRAM model can also be used to quantify how bycatch may reduce prey available to killer whales. The age structure of Chinook in the FRAM model is dominated by 2-year olds (58% 2-year olds, 23% 3-year olds, 15% 4-year olds, 4% 5-year olds), while the biomass is skewed toward older fish (1% 2-year olds, 12% 3-year olds, 57% 4-year olds, 30% 5-year olds). Assuming bycatch occurs relative to their relative abundance, the largest impact can be calculated by focusing on the FRAM period with lowest relative Chinook abundance (July–September).

Table 12: Estimated reduction in prey, July-September in coastal waters, under 2 alternative levels of salmon abundance (~ 3.72 million 2-5 year Chinook in 1994, ~ 10.5 million Chinook in 2002; PS Chinook RMP, L. LaVoy unpublished). Values in the table represent the reduction of Chinook numbers and kilocalories available to killer whales (kilocalorie values impose size-selectiviy from the PS RMP). Values are calculated as 100 x (abundance after bycatch removed / abundance before bycatch removed). In all scenarios, bycatch values would reduce available prey by less than 1%.

Bycatch removed	High salmon (2002)	Low salmon (1994)
2000	0.019% (0.019%)	0.054% (0.039%)
4000	0.038% (0.038%)	0.108% (0.077%)
6000	0.057% (0.058%)	0.162% (0.116%)
8000	0.076% (0.077%)	0.216% (0.155%)
10000	0.095% (0.096%)	0.270% (0.193%)
12000	0.114% (0.115%)	0.324% (0.232%)

Even in years with relatively low Chinook salmon abundance, the relatively high bycatch would only cause a reduction of 0.33% of available Chinook across the whales' coastal range. Because all calculations (Table 12) are based on the period (July-Sept) with relatively low prey availability to need ratios (PS Chinook RMP), these impacts are likely overestimates (ratios are higher in winter months, when the whales are more likely to encounter southern stocks). Given the relatively small impact of bycatch on either numbers or biomass (Table 12), values of bycatch in the range observed are likely to have a negligible impact.

Habitat and trophic effects

Indirect trophic effects of the WCGF fisheries are also expected to be negligible on forage fish species (Appendix A), and effects on killer whales would only occur indirectly through alteration of the food web.

Impact of WCGF fisheries on population growth rate

Southern Resident killer whales are a slow growing population, and although the species is capable of maintaining a 2.3% growth rate (Olesiuk et al. 1990), this population has achieved a growth rate of only 0.4% since the mid-1970s. Previous work has demonstrated links between prey availability (Chinook abundance) and killer whale fecundity and survival (Ward et al. 2009; Ford et al. 2009). The linear relationship between Chinook abundance and probability of calving can be used to evaluate a reduction of 0.25% (Table 12); under this scenario, the probability of a female calving would be reduced by 0.06%. Given that births occur infrequently, and the population is subject to both demographic and environmental stochasticity, such a change would be undetectable. We therefore conclude that the WCGF are likely to have, at most, a negligible effect on the population growth rate of the Southern Resident killer whales.

Chapter 4: Pinnipeds

*Guadalupe Fur Seal (*Arctocephalus townsendi*)*

General Biology[10]

Guadalupe fur seals are a member of the family Otariidae along with other fur seal and sea lion species. They have a dark brown to black coloration and are sexually dimorphic. Adult males are longer (average length of 7 ft) and heavier (average weight of 400 lb) than females (average length of 5 ft and weight of 110 lb). Adult males also typically have a yellow or lighter brown mane on the back of their head and neck as a secondary sexual characteristic. They are terrestrial breeders. During the breeding season of June through August, males form small territories, especially near caves and crevices that they defend through threat aggressive vocal displays from other males (Peterson et al. 1968, Gallo-Reynoso 1994). The mating system is polygynous. Females generally give birth a few days after arriving on the breeding rookery and mate within a week after the pup is born. Mothers must forage during the lactation period, leaving pups on the beach. Mother and pup reunions are mediated by vocal dueting in which both produce individually unique vocalizations. Identity seems to be confirmed by scent. Pups are typically weaned at around nine-months of age. Based on stomach contents of stranded animals, Guadalupe fur seals eat rockfish, mackerel, lantern fish, flatfish, and squid (Hanni et al. 1997).

Range and stock structure

The general range of Guadalupe fur seals extends from the southern tip of Baja California, Mexico to the southern coast of California, USA. Individuals have been sighted as far south as Zihuatanejo, Mexico and as far north as Washington State (Etnier 2002, Aurioles-Gamboa and Hernandez-Camacho 2006). Rare sightings outside the typical range and especially to the north almost always involve juvenile seals during El Nino events (Hanni et al. 1997, Etnier 2002). Most breed on Guadalupe Island, Mexico with much smaller breeding colonies on East San Benito Island, Mexico. Guadalupe fur seals were hunted to near extinction as a result of intense commercial sealing in the 18th and19th century. They have a single stock designation because all individuals are believed to be descendants from a single breeding colony on Guadalupe Island. Archeological and historical evidence indicates that the former breeding range of this species was probably from San Miguel Island, California to Socorro Island, Baja California (NMFS 1985, FR 50 51252).

Habitat use

Guadalupe fur seals prefer rocky islands and caves for terrestrial breeding habitat. Foraging habitat is less well defined. Guadalupe fur seal foraging ecology is believed to be similar to other *Arctocephalus* species. Most species in this genus forage in upwelling zones, oceanic fronts, or

[10] Unless otherwise noted, most information about Guadalupe fur seals was obtained from the most recent Stock Assessment Report (included in Carretta et al. 2009).

continental shelf-edge regions and mainly in the surface mixed layer (<50–60 m) at night (Arnould 2009). Guadalupe fur seals are thought to typically stay in the tropical waters off the coast of Baja California at least during the summer breeding months. Diving behavior has been reported from adult females tagged with time-depth recorders and satellite transmitters. In one study, a few females were tagged on the breeding colony on Guadalupe Island and fed in the California Current south of the island, making round trips from the breeding colony that averaged 2,375 km and ranged from 704 to 4,092 km (n=3, Gallo-Reynoso 1994). Dive data were only successfully collected from one female on a foraging trip that lasted 14 days. Mean dive depth was 16.9 m (range: 3–82 m), mean dive duration was 2.6 min (range: 0.5–18), mean surface interval between dives was 2 min (range: 0.5–26), and mean bottom time was 1.4 min (range: 0–15.5, Gallo-Reynoso 1994). In another study, a stranded female released at Point Piedras Blancas, California was tagged with time-depth recorders and satellite transmitters to track movement after rehabilitation (Landers et al. 2000). Average dive depths and durations in the stranded female were similar to those previously reported in Gallo-Reynoso (1994). In both studies, almost all dives were recorded at night or during crepuscular hours (Gallo-Reynoso 1994, Landers et al. 2000).

Critical habitat and protected area designations

Critical habitat has not been designated for the Guadalupe fur seal under the ESA since current breeding colonies are only located in Mexico (NMFS 1985, FR 50 51252). In Mexico, Guadalupe Island has been designated as a pinniped sanctuary since 1975.

Status

Guadalupe fur seals were listed as threatened under the Endangered Species Act in 1985 and are also listed as a Depleted and Strategic species under the Marine Mammal Protection Act (NMFS 1985, FR 50 51252).

Abundance and trend

Guadalupe fur seal abundance is relatively small compared to other U.S. West Coast pinniped populations. In 1993, the population was estimated to be 7,408 animals (Gallo-Reynoso 1994). The population on San Benito Island increased at a rate of 13.7% per year from the mid-1950s to 1993 (Gallo-Reynoso 1994). Guadalupe fur seal populations on San Benito Islands also experienced a population growth of 18.9% from 1997 to 2006, but this likely represented expansion of the breeding colony from Guadalupe Island (Aurioles-Gamboa et al. 2010). The current population size is estimate to be around 10,000 individuals (Aurioles-Gamboa et al. 2010).

Threats (from Recovery Plan or listing documents)

There is no Recovery Plan prepared for Guadalupe fur seals. Potential threats in the listing document include oil spills, sonic boom exposure from Vandenberg A.F.B., disturbance by tourists and fishing vessels, and potential expansion of gillnet fisheries off of Baja California (NMFS 1985 FR 50 51252).

Fishery Impacts

Fisheries may potentially impact Guadalupe fur seals through several mechanisms, including physical disturbance, acoustic disturbance, entanglement in nets or lines, and direct or indirect reduction of prey. Drift and gillnet fisheries may result in incidental mortality or serious injury to Guadalupe fur seals in the United States and Mexico. Three of nine Guadalupe fur seals stranded in central and northern California in the late 1980s to mid-1990s showed evidence of entanglement in fishing gear or marine debris (Hanni et al. 1997). It is unclear if these injuries were a result of interactions with active fishing sets or a result of fishing gear debris (i.e., ghost fishing).

Impacts, all fisheries

California, Oregon, Washington - There are no U.S. reports of Guadalupe fur seal injury or mortality for any fisheries with onboard observers. This is based on available data from the California commercial fisheries and the West Coast groundfish fishery (Carretta et al. 2004, Carretta and Enriquez 2006, 2007, 2008, 2009a,b, 2010; Jannott et al. 2011). Some reports include unidentified pinnipeds as bycatch mortalities in the California commercial fisheries (Carretta and Enriquez 2009b, Carretta et al. 2004).

The concept of Potential Biological Removal (PBR) is one method of evaluating risk imposed by a particular level of take, which is a key approach in conducting assessments under the Marine Mammal Protection Act. The total U.S. fishery mortality and serious injury for this stock is less than 10% of the calculated PBR and, therefore, can be considered to be insignificant and approaching zero mortality and serious injury rate (Carretta et al. 2009).

Mexico, Central America – There is no information on Guadalupe fur seal injury or mortality for any fisheries in Mexico. The last assessment on potential impacts was included in the 2000 stock assessment report of the species. In the Mexican swordfish and shark fisheries, similar drift gillnets are used as in the Californian swordfish and shark fisheries. The overall bycatch mortality rate is similar to that observed in the California driftnet fisheries during 1990–1993, but this information is not species-specific for Mexican fisheries. Thus, there is insufficient information to determine whether the fishery mortality in Mexico exceeds the PBR for this stock (Carretta et al. 2009).

Impacts, WCGF fisheries

No Guadalupe fur seal injury or mortality has been reported for any WCGF fishery activities. From 2002–2009, one unidentified pinniped was reported off the coast of Oregon (Jannott et al. 2010). Based on the extremely rare occurrence of this species along the Oregon coast, it is highly unlikely that the unidentified pinniped was a Guadalupe fur seal.

Habitat and trophic effects

WCGF fisheries target commercially valuable fish species that include a variety of rockfish, flatfish, roundfish, skates, and sharks (see Chapter 2 Description of the Fisheries). Little is known about what Guadalupe fur seals eat, but they are thought to be generalists, eating a variety of fish and squid that include rockfish and flatfish. Given the potential overlap with prey, it is possible that Guadalupe fur seals will be impacted from direct reduction in prey by WCGF fisheries. However, the geographic range overlap is restricted since Guadalupe fur seals are non-migratory—all breeding grounds are in Mexico, and sightings in U.S. waters are rare.

Impact of WCGF fisheries on population growth rate

The total U.S. fishery mortality and serious injury for this stock is less than 10% of the calculated PBR and, therefore, can be considered to be insignificant and approaching zero mortality and serious injury rate. There are no reports of Guadalupe fur seal bycatch from the WCGF fishery, and habitat and trophic effects are likely small. Thus, impacts on population growth rate are likely to be negligible.

*Steller sea lion (*Eumetopias jubatus*)*

General biology[11]

The Steller sea lion is the largest member of the Otariid (eared seal) family. Males may be up to 325 cm (10–11 ft) in length and can weigh up to 1,100 kg (2,400 lb). Females are smaller than males, 240–290 cm (7.5–9.5 ft) in length and up to 350 kg (770 lb) in mass. Bulls become mature between 3 and 8 years of age, but typically are not massive enough to hold territory successfully until 9 or 10 years old. Females reproduce for the first time at 3 to 8 years of age, and the average age of reproducing females is approximately 10 years. Females bear at most a single pup each year between late May through early July, with peak numbers of births during the second or third week of June. Weaning takes place gradually during the winter and spring prior to the following breeding season, and it is not uncommon to observe 1- or 2-year-old sea lions suckling from an adult female. Females normally ovulate and breed annually after maturity, although because of a high rate of reproductive failures and early pup mortality, estimated birth rates have ranged from 55% to 63%.

Range, migratory behavior, and stock structure

Steller sea lions are found across the North Pacific Ocean rim from northern Japan, the Kuril Islands and Okhotsk Sea, through the Aleutian Islands and Bering Sea, along Alaska's southern coast, and south to California. Pupping and breeding occurs on rookery sites during May to July; most (sexually mature) adult Steller sea lions are found on the rookeries at this time, while most juveniles and non-breeding adults are found on haulouts where pupping rarely occurs. Seal Rocks, at the entrance to Prince William Sound, Alaska, is the northernmost rookery (60°09'N). Año Nuevo Island off the central California coast is the southernmost rookery (37°06'N), although some pups were born at San Miguel Island (34°05'N) up until 1981. At present, the only active rookeries along the Asian coast are in Russia. Prior to the large declines in the western stock of Steller sea lions in the 1980s, the largest rookeries and pup numbers were in the Gulf of Alaska and Aleutian Islands. After the decline, rookeries in the west became progressively smaller; consequently, the largest rookeries are now in Southeast Alaska and British Columbia.

Although Steller sea lions do not make regular migrations, they do move considerable distances. Animals marked as pups on rookeries in the Gulf of Alaska have been sighted in Southeast Alaska and British Columbia; some marked in British Columbia have been seen at Cape Saint Elias, Alaska; some marked in the eastern Aleutians have been seen in eastern Bristol Bay, Alaska; and some marked in Oregon have been seen in northern California, Washington, British Columbia, Southeast Alaska, and the northern Gulf of Alaska (Calkins and Pitcher 1982, Calkins 1986, Loughlin 1997). In their first year, most animals stay within 500 km of their natal rookery. After the first year, juveniles move much greater distances from their natal rookery (up to 1785 km) and may stay distant for 3–7 years. However, when they reach sexual maturity, most animals return to their natal rookery to breed. After the breeding season, adult females remain

[11] This section on general biology is adapted from the following sources, unless a specific citation is given: http://www.afsc.noaa.gov/nmml/alaska/sslhome/biology.php, NMFS (2008), and Allen and Angliss (2011).

generally less that 500 km from their natal rookery, while adult males have been seen over 1,000 km from the rookery where they held a territory (Raum-Suryan et al. 2002, 2004).

Although most adults return to their natal rookery to breed, dispersal of animals from their natal rookeries to establish new rookeries or expand existing ones does occur. In southeast Alaska, new rookeries were established as population size increased. The new rookeries were formed by animals dispersing from nearby rookeries and from rookeries in the Gulf of Alaska and Aleutians (NMFS 2008).

In 1997, NMFS classified Steller sea lions as distinct western and eastern population segments under the ESA based on genetic studies and phylogeographical analyses from across the sea lion's range (62 FR 24345). The eastern distinct population segment (DPS) includes sea lions born on rookeries from California north through southeast Alaska; the western DPS includes those animals born on rookeries from Prince William Sound westward (Bickham et al. 1996, Loughlin 1997). The regulatory division between DPSs is Cape Suckling (144º west longitude) in the northeast Gulf of Alaska (Figure 12). However, frequent movement is seen across this boundary by animals from both populations, particularly juvenile animals (Raum-Suryan et al. 2002). Later genetic studies (Baker et al. 2005, Hoffman et al. 2006) also supported the separation of the eastern and western populations and suggested a third, Asian, population segment.

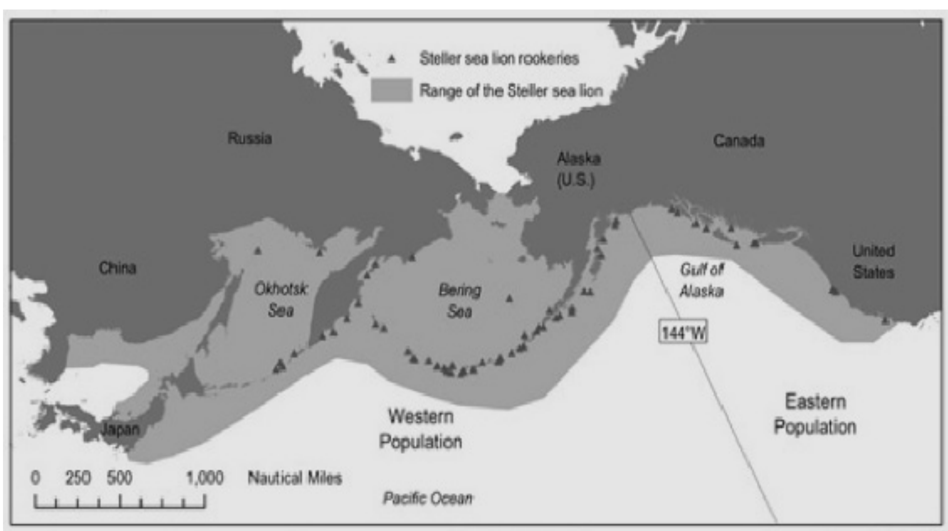


Figure 12: Steller sea lion geographic distribution and demarcation line between the eastern and western DPSs. (Figure from AFSC/NMML)

Habitat use

Steller sea lions use both terrestrial and marine habitat. Terrestrial habitat is categorized as haulouts and rookeries. Haulout is the term used to describe terrestrial areas used by adult sea lions during times other than the breeding season and by non-breeding adults and juveniles throughout the year. During the breeding and pupping season, females use rookery sites to give birth, and they select places that are gently sloping and protected from waves. Pups stay on land for approximately two weeks and then begin swimming close to shore. When pups are approximately 2.5-months old, females begin dispersing with their pups away from rookeries to haulouts. These haulouts may be considerably rockier and more exposed. During the breeding and pupping season, territorial adult males also spend considerable amounts of time on rookeries while they defend harems and breed. Individual Steller sea lions, especially adults, display strong site fidelity to specific haulouts and rookeries from year to year.

Studies using satellite telemetry in Alaska have provided detailed information on the use of marine habitat by adult and juvenile Steller sea lions. Overall, available data suggest two types of marine habitat use. Juveniles, pups, and lactating females normally stay less than 20 km from rookeries and haulout sites. Foraging trips by lactating females are typically less than 24 hours, but sea lions which are not longer tied to land, due to sufficient age or less of a need to return to land to nurse or reproduce, will forage over much larger areas (greater than 20 km) to find optimal foraging conditions. During longer range foraging trips, animals are commonly found near and beyond the 200 m depth contour (NMFS 2008). They may also be found farther out to sea in water greater than 1,000 m deep (Merrick and Loughlin 1997). In California, animals have been observed to forage up to 85 miles off-shore (Fiscus and Baines 1966). Large seasonal differences in foraging ranges have been observed in Steller sea lions (Loughlin 1993, Merrick 1995), and these seasonal changes appear to be related to seasonal movements of prey.

Critical habitat

On 27 August 1993, NMFS published a final rule to designate critical habitat for the threatened and endangered populations of Steller sea lions (58 FR 45269). Two kinds of marine habitat were designated as critical: "aquatic zones" around rookeries and haulouts and three special aquatic feeding areas in Alaska. Aquatic zones extend 3,000 feet (0.9 km) seaward in state and federally managed waters from each major rookery and major haulout in Alaska that is east of 144°W longitude and each major rookery in California and Oregon (Figure 13). Aquatic zones in the U.S. breeding range of the western DPS extend 20 nm (37 km) seaward in state and federally managed waters from each major rookery and major haulout in Alaska that is west of 144°W longitude. The three special aquatic foraging areas in the critical habitat are in the western DPS range: Shelikof Strait, the southeastern Bering Sea north of the Aleutian Islands from Unimak Island past Bogoslof Island to the Islands of Four Mountains, and Seguam Pass.

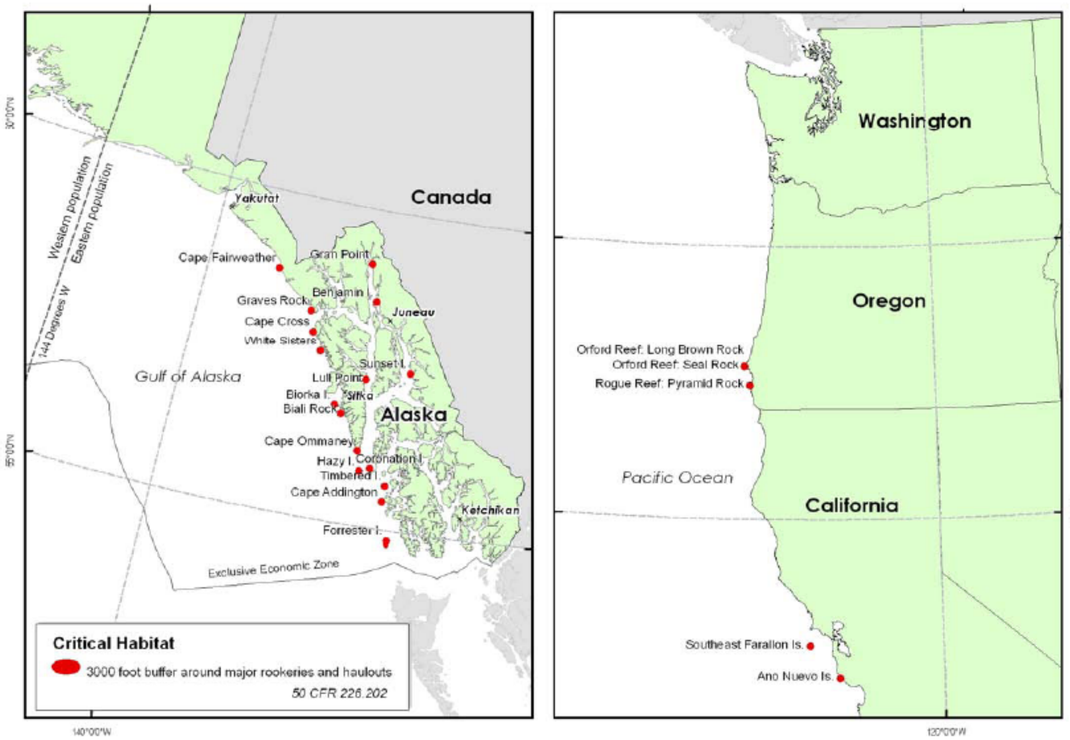


Figure 13: Designated critical habitat for the eastern DPS (50 CFR 226.202) (reprinted from NMFS 2008). The designated critical habitat includes three major rookeries in Oregon and three in California. The third Californian rookery is not marked but is just above the 40deg line in the figure. There are no major rookeries in Washington.

Status

Under the MMPA, all Steller sea lions are classified as strategic stocks and are considered depleted. In 1990, after large range-wide declines, the Steller sea lion was listed under the ESA as threatened throughout its range (55 FR 12645, 5 April 1990; 55 FR 50005, 4 December 1990). This listing included animals from Alaska, California, Oregon and Washington in the U.S., as well as Canada, Japan, and Russia. On 4 June 1997, the population west of 144°W longitude was listed as an endangered DPS (the western DPS) under the ESA; the population east of 144°W (the eastern DPS) remained listed as threatened as the eastern DPS. A Recovery Plan was developed for Steller sea lions in 1992. A revised Recovery Plan, which discusses separate recovery actions for the threatened and endangered DPSs, was issued in 2008. On 13 December 2010, NMFS announced a decision to review the status of the eastern DPS in response to two petitions to delist the eastern DPS (75 FR 77602).

Abundance and trend

The western DPS, comprising animals in the Asian, Aleutian Islands, and Gulf of Alaska regions, steadily decreased from an estimated 220,000–265,000 animals in the late 1970s to fewer than 50,000 in 2000 (NMFS 2008). However, the rate of decline steadily decreased, and by 2000, increases in adults and juveniles were observed in the eastern and western Gulf of Alaska and in the eastern and central Aleutian Islands. Overall, a 3% per year increase was observed during the 2000–2004 period across the entire western DPS despite stable or declining numbers in the central Gulf of Alaska and the western Aleutian Islands. The region-wide increases did not continue after 2004, however. Instead, between 2004 and 2008, numbers were stable (not increasing) overall with regional differences. In the eastern Aleutians, numbers increased while they decreased in the central and western Aleutians. Numbers were stable in the western and central Gulf of Alaska and increased in the eastern Gulf of Alaska due to movement of animals into the region from southeast Alaska. The most recent counts in 2010 have found similar trend patterns (Fritz and Gelatt 2010). The number of Steller sea lions in the western DPS in 2005 was estimated at approximately 61,000 (NMFS 2008); subsequent surveys in the Gulf of Alaska, Aleutians, and Russia suggest that the western DPS has increased by approximately 4% since 2005 (Allen and Angliss 2011, Burkanov 2009).

In contrast, the eastern DPS, comprised of animals in Southeast Alaska, British Columbia, Washington, Oregon, and California, did not experience large declines in the early 1980s and has increased at over 3% per year since the late 1970s (Allen and Angliss 2011). Numbers have more than doubled in southeast Alaska, British Columbia, and Oregon, and counts on the Saint George Reef rookery and Sugarloaf rookery in northern California are near levels recorded early in the 20th century. However, numbers of animals at the southernmost California rookeries are at historically low levels (Sydeman and Allen 1999; Allen and Angliss 2011); the Año Nuevo rookery and the Farallon Islands in central California are substantially reduced (90% lower) from those reported early in the 20th century, and the former haulout/rookery at San Miguel Island is now extinct, as are several other sites previously used in California. The reasons for the large declines in southern and central California are not known; however, more recently, the numbers in California have been relatively stable albeit low. Despite declines in California, overall the eastern DPS (CA, OR, WA, BC, and SE AK together) is increasing due to positive trends in the northern regions of the DPS. Total population size of the eastern DPS in 2002 was estimated to range between 45,000 and 51,000 animals of all ages (NMFS 2008). Additional surveys in California, British Columbian and southeast Alaska after 2002 suggest the population has continued to increase since the 2002 survey. Based on the 2006-2009 pup counts, the population is currently estimated to be between 58,334 and 72,223 (Allen and Angliss 2011). Southeast Alaska and British Columbia together account for over 80% of total pup production occurring in the eastern population, and four new rookeries have been founded in the last 25 years in southeast Alaska at the northern extent of the population range. During the 1970s, the eastern DPS contained approximately 10% of the total number of Steller sea lions in the U.S., but currently over half of U.S. Steller sea lions now belong to the eastern DPS, and Pitcher et al. (2007) reported that 55% of the pup production of Steller sea lions in the U.S. currently occurs in the eastern population.

Threats (from Recovery Plan or listing documents)

The threats discussed in the Steller Sea Lion Recovery Plan (NMFS 2008) include both natural factors, which may not be controllable, and mitigable human-related factors:

- Large-scale fishery removals that reduce the availability or quality of prey species;
- Large-scale environmental changes that affect the abundance or distribution of prey species;
- Predation from killer whales, especially, and sharks;

- Nonlethal diseases that affect survival or fecundity and/or reduce the foraging efficiency of sea lions;
- Pollutants concentrated through the food web that contaminate fish eaten by sea lions, possibly reducing their fecundity or increasing mortality;
- Incidental takes of sea lions through capture or entanglement in fishing gear that increased as a result of the expansion of commercial fisheries;
- Takes of sea lions in the subsistence harvest; and
- Shootings of sea lions unrelated to the subsistence harvest.

Fishery impacts

Fisheries may potentially impact Steller sea lions through several mechanisms, including physical disturbance, injury or mortality from entanglement in nets or lines, and direct or indirect reduction of prey (NMFS 2008). Due to limited movement of Steller sea lions in the western DPS into Washington, Oregon, or California waters and minimal movement of Washington, Oregon, and California animals into the western DPS, the discussion of fishery impacts will focus exclusively on the impacts of the West Coast fisheries on the eastern Steller sea lion DPS. The stock assessment report (Allen and Angliss 2011) divides estimates of fishery-related mortality into those derived from fishery observer programs and those derived from data on entanglement with fishing gear. Serious injury and mortality for entanglement from fishing gear is listed under impacts for all fisheries, using both entanglement data in the 2010 stock assessment and additional data reported in west coast standing and entanglement surveys. Impacts from the WCGF fisheries are estimated from data in the West Coast Groundfish and At-Sea Hake Observer Programs.

Impacts, all fisheries

Strandings of Steller sea lions provide information on the level of fishery-related mortality due to entanglement with gear from all fisheries. The latest stock assessment report (Allen and Angliss 2011) includes data on "flasher" entanglement from the salmon troll fishery. During a 5-year period, three flasher entanglements were observed giving an observed mortality of 0.6 animals per year from the salmon troll fishery. This is a minimum estimate from one fishery. Data from entanglement surveys and the NOAA Marine Mammal Stranding network give us a more comprehensive estimate of entanglement rates.

Entanglement of Steller sea lions in the eastern DPS has been estimated at 0.26% based on surveys of 69 sites in southeast Alaska and British Columbia (Raum-Suryan et al. 2009). The majority of observed entanglements were fishing gear or debris related and were around the neck. Using the 2009 N_{min} abundance (52,847; Allen and Angliss 2011), this translates to an estimated 115 entangled animals in the population at any one time (52847 x 0.0026 = 137). The entanglement rate observed in SE Alaska and British Columbia is used for the whole eastern DPS, since Steller sea lion-specific entanglement data are not available in other regions but the rate observed in SE Alaska and British Columbia is similar to that observed in California across all pinnipeds (0.07–0.22%). Mortality rates due to entanglements is unknown; of 14 branded individuals with entanglements, 5 disappeared and 9 were still known to be alive at the end of the 7-year study (Raum-Suryan et al. 2009). If we assume 36% mortality of entangled individuals (5 out of 14), this translates to an estimated 49 (137 x 0.36) deaths due to entanglement over a 7-year period, or approximately 7 animals per year in the eastern DPS.

A second estimate of the total number of entangled individuals can be obtained from the NOAA Marine Mammal Stranding network. The numbers of stranded Steller sea lions reported by the NOAA Marine Mammal Stranding network between 1999 and 2010 are shown in Table 13. The proportion of strandings that are fishing related have only been reported for southeast Alaska, and proportions have ranged from 10 to 50%. In Washington and Oregon, California, on total strandings are reported; the numbers of standings that are fishery related are not reported. To estimate the total fishing-related strandings (Table 13), an estimate of the total strandings across all regions was multiplied by the proportion of strandings that were fishing-related in the southeast Alaska data. The number of stranded Steller sea lions has increased in recent years, as has the proportion of these strandings that were attributed to fishing interactions (entanglement with fishing debris or ingestion of gear, typically). Taken together with the entanglement study by Raum-Suryan et al. (2009), the data from the NOAA stranding reports suggest a minimum mortality of 5–40 animals per year in Washington and Oregon, California, and southeast Alaska may be attributable to entanglement with or ingestion of fishing gear of some type. Some of the human-related mortalities were gunshot wounds, but these numbers were very small. This is a minimum estimate since observed strandings represent only a fraction of the actual strandings.

Table 13: Numbers of stranded Steller sea lions reported by the NOAA Fisheries Marine Mammal Stranding Network for Washington and Oregon, California, and southeast Alaska. In southeast Alaska, strandings due to human interaction (typically fishing) are reported and are shown in parentheses where available. Strandings for 1999-2002 in southeast Alaska are the average over 4 years. Estimated fishing-related strandings are computed using total strandings across all regions (or 2 x SE AK when WA/OR and CA numbers are unavailable) times the observed proportion of strandings that are fishing related in SE AK (= number in parentheses in SE AK column divided by the number outside parentheses in SE AK column).

	WA/OR	**CA**	**SE AK**	**Estimated fishing related strandings (WA/OR+CA+SE AK)**
1999	3	11	17	---
2000	5	10	17	---
2001	4	13	17	---
2002	5	6	17	---
2003	16	9	23 (3)	6
2004	16	7	9 (2)	7
2005	NA	13	12 (3)	6
2006	NA	15	25	---
2007	NA	NA	28 (13)	26
2008	NA	NA	36 (10)	16
2009	NA	NA	49 (8)	20
2010	NA	NA	45 (18)	36

Impacts, WCGF fisheries

In the eastern DPS, Steller sea lion serious injuries and mortalities have been reported by fisheries observers in the California (CA)/Oregon (OR) thresher shark and swordfish drift gillnet, the West Coast groundfish, the Northern Washington (WA) marine set gillnet, and the Gulf of Alaska sablefish longline fisheries (Allen and Angliss 2010). However in recent years (after 2000), fisheries observers have only reported serious injuries and mortalities in the West Coast groundfish fishery, although no data are available after 1998 for the Northern Washington marine set gillnet fishery (Allen and Angliss 2011). The latest stock assessment report (Table 5; Allen and Angliss 2011) gives a serious injury and mortality estimate of 0.8 animals per year based on the Pacific whiting component of the WCGF fisheries. We can obtain estimates of annual serious injury and mortality across all components of the fishery from reports of the West Coast Groundfish and At-Sea Hake Observer Programs (Jannot 2011).

Over the period from 2002–2009, a total of 8 Steller sea lion serious injuries or mortalities were observed in the West Coast Groundfish Program, and 11 serious injuries or mortalities were observed in the At-Sea Hake Observer Program (Table 7i, Jannot 2011). The estimated total (as opposed to observed) serious injuries or mortalities in the two fisheries together for the 2002–2009 period was 44 Steller sea lions with upper and lower 90% confidence intervals of 18 and 111 serious injuries or mortalities (estimates and confidence intervals are those reported in Jannot 2011). The numbers of serious injuries or mortalities has varied across years and has been increasing the last five years (Figure 14).

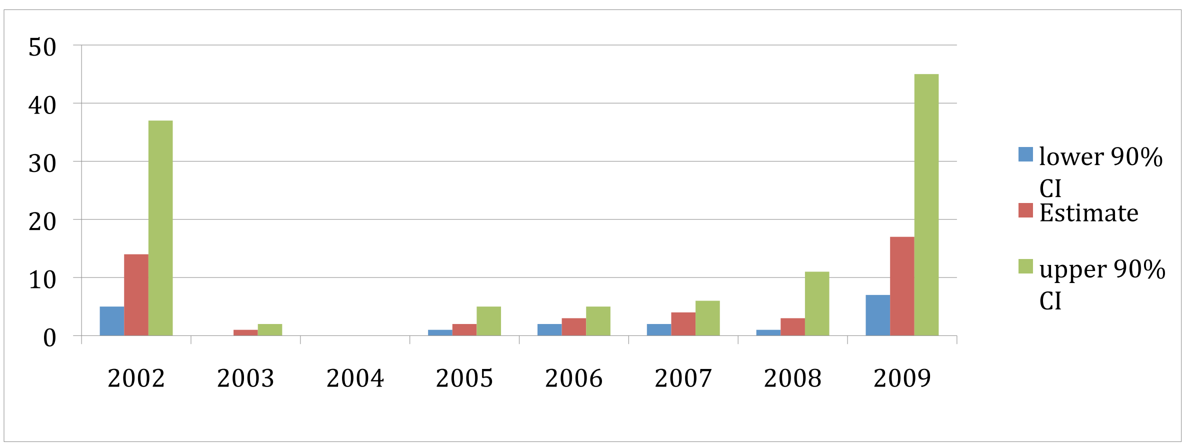


Figure 14: Estimated total Steller sea lion serious injuries or mortalities from the combined At-Sea Hake fishery and West Coast Groundfish fishery (from Table 7i, Jannot 2011).

Habitat and trophic effects

The most commonly identified prey in southeast Alaska includes walleye pollock, Pacific cod, flatfishes, rockfishes, herring, salmon, sand lance, skates, squid, and octopus (Calkins and Goodwin 1988, Trites et al. 2007). Principal prey in British Columbia includes hake, herring, octopus, Pacific cod, rockfish, and salmon (Spalding 1964, Olesiuk et al. 1990). In California and Oregon, Steller sea lion prey is known to include rockfish, hake, flatfish, salmon, herring, skates, cusk eel, lamprey, squid, and octopus (Fiscus and Baines 1966, Jameson and Kenyon 1977, Jones 1981, Treacy 1985, Brown et al. 2002), with the primary prey items being, in order of frequency of occurrence in scat, Pacific hake (in 78.6% of scat), Pacific salmon (28.6%), skate (23.4%), Pacific lamprey (20.8%), clupeid (herring, shad, sardine) species (18.7%) and rockfish (17.4%) (Riemer et al. 2010).

Steller sea lion diet includes commercially valuable fish species, and the WCGF fisheries target many of the same species found in Steller sea lion diet, especially hake (Pacific Whiting), rockfish, and various mid-water and bottom fish (see Chapter 2 Description of the Fisheries). The Atlantis simulations described in Appendix A suggest that current levels of fishing are having impacts on the predominant prey of Steller sea lions (hake aka Pacific Whiting). Under case study 2, the unfished biomass of hake was projected to be 10.46 times higher, and under case study 3, the unfished biomass of hake was projected to be 1.94 times higher. Note in Appendix A, the impact of the WCGF fisheries on pinnipeds is simulated; however, Steller sea lions are the largest of the pinnipeds on the U.S. west coast and their diet is skewed towards larger fish relative to that shown in Table 1 of Appendix A where cephalopods (squid) are listed as comprising approximately 45% of pinniped diet and hake as ca. 20%. In contrast, hake are the dominant prey in Steller sea lion diet and cephalopods are much less common (Riemer et al. 2010). Thus the Altantis results for pinnipeds as a whole are not necessarily indicative of results for Steller sea lions.

The WCGF fisheries target important Steller sea lion prey and there exists the potential for fishery-induced prey depletion (as suggested by the Atlantis simulations in Appendix A). Quantifying the impact of fishery-induced prey depletion has been the object of much research in the western DPS (summarized in NMFS 2008). However, establishing direct links has proven to be very difficult. Nonetheless, the clear potential for impacts has led to the conclusion that the potential for impacts on Steller sea lions is high (NMFS 2008), and this has led to extensive regulations on fisheries operating within Steller sea lion foraging areas in the western DPS (which in contrast to the eastern DPS has been declining or, more recently, stable). Likewise, in the eastern DPS, establishing the effects of prey depletion on survival and fecundity of Steller sea lions is likely to be quite difficult, but these effects can reasonably be assumed to be present due to the spatial overlap of the fisheries with the species' foraging areas. Nonetheless, at current levels of fishing-induced prey depletion (to the extent that it is occurring), the Steller sea lion population in the eastern DPS has been increasing by 3% per year for approximately 20 years (Allen and Angliss 2011). This suggests that any fishing-induced prey depletion, at least over the last 20 years, has not prevented steady population increases in the eastern DPS.

Impact of WCGF fisheries on population growth rate

Because we have no way to quantify the effects of (possible) prey depletion on Steller sea lion population growth rate, we estimate the impact of WCFC fisheries on population growth rate based only on serious injuries and mortalities due to fisheries operations (reported by the fishery observer programs) and due to entanglements with fishing gear (estimated).

Under the 1994 reauthorized Marine Mammal Protection Act (MMPA), the potential biological removal (PBR) is defined as the product of the minimum population estimate, one-half the maximum theoretical net productivity rate, and a recovery factor: PBR = N_{min}* 0.5 R_{max} x F. The default recovery factor (F) for stocks listed as "threatened" under the Endangered Species Act (ESA) is 0.5 (Wade and Angliss 1997). However, in the 2011 stock assessments, the recovery factor was set at 0.75—midway between 0.5 (recovery factor for a "threatened" stock) and 1.0 (recovery factor for a stock within its optimal sustainable population level)—because the eastern DPS numbers have remained stable or have increased over the last 20 years. For the eastern Steller sea lion DPS, current (2010) N_{min} = 52,847 (Allen and Angliss 2011) and R_{max} is assumed to be 12% using the maximum theoretical pinniped net productivity rate. The result is a PBR of 2,378 animals (52,847 x 0.5 x 0.12 x 0.75). In comparison, the estimated total fishery takes over the 8-year period of 2002–2009 were 44 animals (= 5.5 animals per year), and the estimate for 2009 was between 7 to 45 animals (Figure 14).

The estimate of total fishing bycatch take (West Coast Groundfish fishery and At-Sea Hake fishery together) in 2009 was 17 (90% CI 7-45) (Figure 14; Table 7i, Jannot 2010). Our rough estimate of mortality related to entanglement in 2010 is 36. If the true level of take associated with fisheries is close to these estimates, this would suggest that mortality from bycatch and entanglement from the WCGF has a minor impact on the rate of population growth. For example, at the current estimated growth rate of 3.1% and 2010 N_{min} abundance (52,847), the population is growing at ~1,638 individuals annually. If one assumes that this would increase by a maximum of 81 individuals (17 from 2009 in in Figure 14 + 36 from 2010 in Table 10) in the absence of fishing, this translates into a population growth rate of ~3.3%. This is a difference of only 0.2%. This calculation assumes that all estimated estimated mortality from entanglement with fishing gear (Table 10) is due to the fishing gear from the WCGF fisheries, which is unlikely to be the case since other fisheries, recreational and commercial, also operate in the region.

Summary

Based on the information summarized above, we conclude that the West Coast Groundfish fisheries are imposing some minor additional (non-natural) mortality on Steller sea lions. However, the population has been increasing steadily, and the current estimated serious injuries and mortalities from the fishery are far below the PBR level. From this, we conclude that recent impacts from fishing are not substantially impacting the eastern DPS abundance as a whole. It should be kept in mind, however, that the southernmost portion of the eastern DPS has contracted, and the southernmost active rookery, at Año Nuevo Island, although apparently stable, is at a historically low population size. Population growth in the eastern DPS is due to population growth in the northern regions of the DPS (Allen and Angliss 2011).

Chapter 5: Fish

*Eulachon (*Thaleichthys pacificus*)*

General Biology

Eulachon, *Thaleichthys pacificus*, is an anadromous smelt in the family Osmeridae that ranges from northern California to the southeastern Bering Sea coast of Alaska (Hay and McCarter 2000, Willson et al. 2006, Moody and Pitcher 2010). Adult eulachon spawn in the lower portions of rivers that have prominent spring peak flow events or freshets, typically at age 2–5, when they are 160–250 mm in length (fork length) (Hay and McCarter 2000, Willson et al. 2006). Many rivers within the range of eulachon have consistent yearly spawning runs; however, eulachon may appear in other rivers only on an irregular or occasional basis (Hay and McCarter 2000, Willson et al. 2006). The spawning migration typically begins when river temperatures are between 0°C and 10°C, which usually occurs between December and June. Run timing and duration may vary interannually, and multiple runs occur in some rivers (Willson et al. 2006). Most eulachon are semelparous. Fecundity ranges from 7,000–60,000 eggs, which are approximately 1 mm in diameter. Milt and eggs are released over sand or coarse gravel. Eggs become adhesive after fertilization and hatch in 3 to 8 weeks depending on temperature. Newly hatched larvae are transparent, slender, and about 4 to 8 mm total length. Larvae are transported rapidly downstream by spring freshets to estuaries (Hay and McCarter 2000, Willson et al. 2006), and juveniles disperse onto the continental shelf within the first year of life (Hay and McCarter 2000, Gustafson et al. 2010). In research trawl surveys, most juvenile eulachon are taken at around 100 m depth in British Columbia (Hay and McCarter 2000) and between 137 and 147 m off the U.S. West Coast (defined as Washington, Oregon, and California) (see references in Gustafson et al. 2010). In the western Gulf of Alaska, eulachon (58 to 205 mm standard length) concentrate over the shelf in proximity to sea valleys (Wilson 2009) where, in contrast to other small neritic fishes, they feed almost exclusively on euphausiids (Wilson et al. 2009).

Marine Habitat Use

Although they spend 95–98% of their lives at sea (Hay and McCarter 2000), little is known concerning the marine existence of eulachon. They are reported to be present in the "food rich" and "echo scattering layer" of coastal waters (Barraclough 1964, p. 1,337), and "in near-benthic habitats in open marine waters" of the continental shelf between 20 and 150 m depth (Hay and McCarter 2000, p. 14). Hay and McCarter (2000, their Figure 5) mapped the offshore distribution of eulachon in British Columbia as determined in research trawl surveys, and indicated that most eulachon were taken at around 100 m depth, although some were taken as deep as 500 m and some at less than 10 m. Schweigert et al. (2007, p. 11) stated that "the marine distribution of adults in British Columbia includes the deeper portions of the continental shelf … generally at depths of 80–200 m." Smith and Saalfeld (1955, p. 12) reported the occasional capture of eulachon in the offshore "otter trawl fishery," particularly in November to January near the mouth of the Columbia River "as the mature smelt approach the Columbia River." Emmett et al. (2001) reported the capture of small numbers of eulachon by nighttime surface trawls targeting pelagic fishes off the Columbia River in April to July of 1998 and 1999. About

10% of hauls in 1999 contained between one and eight eulachon (Emmett et al. 2001). Eulachon also occur as bycatch in some U.S.-based groundfish fisheries (Bellman et al. 2011) off the U.S. West Coast and more commonly in the California and Oregon ocean shrimp (*Pandalus jordani*) fisheries (NWFSC 2008, Bellman et al. 2011). Eulachon are not an actively managed or monitored species (PFMC 2008); therefore, there is a paucity of data on at-sea distribution of eulachon off the U.S. West Coast.

Fishery-independent surveys conducted off the U.S. West Coast that provide data on distribution or abundance of eulachon in the ocean are very limited (Gustafson et al. 2010, their Table A-4). The Northwest and Alaska Fisheries Center (NWAFC, before it split into NWFSC and Alaska Fisheries Science Center (AFSC)) and AFSC conducted groundfish trawl surveys on the continental slope (at depths of 184–1,280 m) periodically from 1984 to 1987 and annually beginning in 1988. Continental shelf (at depths of 55–183 m) surveys were conducted triennially from 1977 to 2001 by the NWAFC and AFSC. The NWFSC assumed responsibility for the slope portion of the groundfish survey starting in 1998 and expanded the depth coverage to include the continental shelf as well as the continental slope in 2003. These groundfish surveys report landings from one of five International North Pacific Fisheries Commission (INPFC) statistical areas. These INPFC areas from north to south are: (1) Vancouver (U.S.-Canada border to 47°30′N latitude); (2) Columbia (47°30′ to 43°00′N latitude); (3) Eureka (43°00′ to 40°30′N latitude); (4) Monterey (40°30′ to 36°00′N latitude); and (5) Conception (36°00′N latitude to the U.S.-Mexico border).

Eulachon were reported in the triennial groundfish bottom trawl surveys on the U.S. West Coast continental shelf in 1977 (Gabriel and Tyler 1980), 1980 (Coleman 1986), 1983 (Weinberg et al. 1984), 1986 (Coleman 1988), 1989 (Weinberg et al. 1994a, 1994b), 1992 (Zimmermann 1994, Zimmermann et al. 1994), 1995 (Wilkins 1998, Wilkins et al. 1998), 1998 (Shaw et al. 2000, Wilkins and Shaw 2000), and 2001 (Weinberg et al. 2002, Wilkins and Weinberg 2002) (Gustafson et al. 2010, their Table A-4). These surveys targeted rockfish from 1977 to 1986, and they were subsequently designed to estimate Pacific hake (*Merluccius productus*) and juvenile sablefish (*Anoplopoma fimbria*) abundance, as well as other commercially important groundfish (Weinberg et al. 1994a). However, these groundfish surveys were designed to sample bottom dwelling species and capture only a small and erratic portion of the distribution of eulachon.

The 1977 shelf groundfish survey recorded eulachon in six of nine assemblages off the Washington and Oregon coasts, being most abundant within the Nestucca Intermediate Assemblage (90–145 m) off Oregon (Gabriel and Tyler 1980). Trawl surveys in 1980–1986 occurred between Monterey Bay, California, and either Northern Vancouver Island (1980), Estevan Point, Vancouver Island (1983), or the U.S.-Canada border (1986) at depths of 55–366 m (Coleman 1986, 1988, Weinberg et al. 1984). From 1989 to 2001, triennial groundfish bottom trawl surveys covered all West Coast INPFC areas from Vancouver to Monterey, inclusive. In 1980, eulachon were recorded as the fifteenth most common fish encountered at depths of 55–183 m in the INPFC Eureka area, but they were not recorded within the top 20 species encountered in the INPFC Vancouver, Columbia, or Monterey areas (Coleman 1986). Latitudinal and longitudinal range and minimum, maximum, and mean depth distribution of eulachon captured in the triennial surveys from 1989 to 2001 are provided in Gustafson et al. (2010, their

Table A-4). Eulachon were found into the far south Monterey INPFC area in the 1989 survey but were not recorded in either the Monterey or Eureka INPFC areas in surveys conducted between 1992 and 2001. Mean depth of occurrence of eulachon in these surveys varied between 137 and 147 m, with minimum depths of 59–79 m and maximum depths of 322–466 m (Gustafson et al. 2010, their Table A-4).

Eulachon were occasionally sampled in West Coast upper continental slope groundfish trawl surveys conducted between 1984 and 1999 by the NWAFC and AFSC (Raymore and Weinberg 1990, Parks et al. 1993, Lauth et al. 1997, Lauth 1997a, 1997b, 1999, 2000) and between 1999 and 2002 by the NWFSC (Builder Ramsey et al. 2002, Keller et al. 2005, 2006a, 2006b). These surveys covered habitat between 183 and 1,280 m from the U.S.-Canada border to 30°30′N latitude (Lauth et al. 1997, Lauth 1997a, 1997b, 1999, 2000, Keller et al. 2005, 2006a, 2006b), although annual surveys prior to 1997 covered only a portion of the area each year (Gustafson et al. 2010, their Table A-4). Minimum, maximum, and mean depths of eulachon captured during the 1989–2002 survey years are given in Gustafson et al. (2010, their Table A-4); however, eulachon were seldom encountered at these depths (below 183 m) and their reported occurrence in trawl hauls ranged from 6% of trawls conducted between 1989 and 1993 to fewer than 1% of all trawls in 2001. Presumably, eulachon were not encountered during the NWFSC 1999 bottom survey of the U.S. West Coast continental slope, as this species is not included in the comprehensive list of species encountered (Builder Ramsey et al. 2002). Eulachon were captured as deep as 608 m during the 2001 survey (Keller et al. 2005).

Starting in 2003, the NWFSC conducted combined slope and shelf surveys for groundfish between depths of 55 and 1,280 m (Keller et al. 2007a, 2007b, 2008) off the U.S. West Coast (Gustafson et al. 2010, their Table A-4). Sampling in these slope and shelf surveys, in contrast to the NWAFC and AFSC triennial bottom trawl surveys (discussed above), did not extend into the Canadian portion of the Vancouver INPFC area where the triennial surveys had encountered the majority of eulachon. Eulachon were found at depth extremes of 51 to 237 m in the NWFSC surveys, with mean depths of 119 to 130 m during the three survey years (Gustafson et al. 2010, their Table A-4) (Keller et al. 2007a, 2007b, 2008); however, eulachon biomass estimates were not presented in these survey documents. Some eulachon were found as far south as 34°N in the INPFC Conception area in 2003 and 2004 (Keller et al. 2007a, 2007b), a southern distribution that had not been recorded in groundfish surveys since 1989 (Weinberg et al. 1994a) (Gustafson et al. 2010, their Table A-4). Pacific hake trawl surveys in U.S. and Canadian waters off the Pacific Coast have also reported incidental catch of eulachon (Fleischer et al. 2005, 2008), although details on catch location were not provided.

The at-sea distribution of eulachon as encountered as bycatch in the West Coast ocean shrimp (aka, pink shrimp) fishery were mapped in Bellman et al. (2011, their fig. 6). Furthermore, Bellman et al. (2011) showed that eulachon were most likely to be encountered as bycatch in tows observed by West Coast Groundfish Observer Program (WCGOP) fisheries from about 91–183 m in depth, although the greatest numbers of eulachon were caught between about 110 and 155 m depth.

Status

Listing status/history

On 27 November 2007, the National Marine Fisheries Service (NMFS) received a petition (Cowlitz Indian Tribe 2007) seeking to list southern eulachon (*Thaleichthys pacificus*) as a threatened or endangered species under the Endangered Species Act (ESA) of 1973. NMFS determined that the 27 November 2007 petition did present substantial scientific and commercial information, or cited such information in other sources, that the petitioned action may be warranted; subsequently, NMFS initiated a status review of eulachon in Washington, Oregon, and California and formed the Eulachon Biological Review Team (BRT)—consisting of scientists from the Northwest Fisheries Science Center, Alaska Fisheries Science Center, Southwest Fisheries Science Center, U.S. Fish and Wildlife Service, and U.S. Forest Service. The BRT determined that eulachon spawning in Washington, Oregon, and California rivers are part of a DPS, composed of numerous sub-populations, that extends beyond the conterminous United States and that the northern boundary of the DPS occurs in northern British Columbia south of the Nass River (most likely) or in southern British Columbia north of the Fraser River (less likely). The BRT found it difficult to establish a clear northern terrestrial or river boundary for this DPS in light of the fact that the BRT believed the northern boundary to be determined by oceanographic processes (Gustafson et al. 2010). NMFS (2010) listed the southern DPS of eulachon—consisting of sub-populations spawning in rivers south of the Nass River in British Columbia, Canada, to, and including, the Mad River in California—as threatened. This listing became effective on 17 May 2010.

Abundance and trends

Although eulachon populations have been exploited for centuries, the historically high abundance of the resource and its low commercial value resulted in limited regulation of past commercial and recreational fisheries, limited recording of past catches, and until recently, a lack of assessment surveys of spawning abundance. Spawning stock biomass (SSB) has been estimated since 1995 for the Fraser River subpopulation, but earlier population sizes in the Fraser and abundance of most other subpopulations can only be inferred from catch statistics and anecdotal information. This lack of fishery-independent surveys makes it very difficult to quantify trends in eulachon abundance. Inferring population status or even trends from yearly changes in catch statistics requires assumptions that are seldom met, including similar fishing effort and efficiency, assumptions about the relationship of the harvested portion to the total portion of the stock, and statistical assumptions, such as random sampling. However, in many parts of the DPS, catch statistics provide the only available quantitative data source that defines the relative abundance of eulachon. Although the magnitude of past commercial fisheries landings in the Columbia River and its tributaries establish that this basin once supported the largest eulachon run in the world (Hay and McCarter 2000), scientific estimates of SSB or number of spawning fish are unavailable.

The Fraser River SSB is the longest running (since 1995) fisheries-independent abundance estimator of spawning biomass for any subpopulation in the DPS. The SSB is generated from counts of eggs and larvae in plankton tows, combined with river discharge rates, sex ratio, and relative fecundity (eggs produced per gram of eulachon) to estimate metric tons of spawning adults (Hay et al. 2002). Spawner biomass for the 2010 eulachon run in the Fraser River was estimated at 4 mt (data and methodology online at: [http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm]) (see Gustafson et al. 2010, their fig. 28). Over the most recent three-generation time of approximately 10 years, these data indicate that the overall biomass of the Fraser River eulachon population has declined by over 97% (2000, 130 t; 2010, 4 t). Given mean weight estimates of Fraser River eulachon (40.6 g; Hay et al. [2002]), these biomass declines represent a reduction in the number of adult eulachon spawning in the Fraser River from about 3.2 million to less than 100,000 over the past ten years. The Fraser River eulachon spawner abundance trend over the time period of the available data (1995–2010) shows a trend of 0.75 (95% CI = 0.66–0.84), indicative of a downward trend in population abundance.

Two fisheries-independent indices of juvenile biomass were available that indicate status of current offshore stock mixtures: (1) a West Coast Vancouver Island eulachon biomass index, and (2) a Queen Charlotte Sound eulachon biomass index (see Gustafson et al. 2011, their fig. 4). The biomass indices of juvenile eulachon in the above two offshore surveys are one to two orders of magnitude greater than known or suspected freshwater eulachon spawning stock biomass in the DPS. The reasons for this apparent discrepancy are not fully understood; however, (1) these offshore estimates are “indices” based on bycatch of eulachon in fishery-independent shrimp trawl surveys and not absolute biomass estimates; (2) production from two or more year classes of eulachon are incorporated into the index estimates; and (3) these two (or more) cohorts (age 1+, age 2+, etc.) may experience substantial mortality prior to their freshwater spawning migration. Although biomass estimates of eulachon off the U.S. West Coast, as estimated from the AFSC triennial groundfish bottom trawl surveys on the continental shelf (55–500 m), have been published for 1995, 1998, and 2001 (see Gustafson et al. 2010), data for eulachon from more recent fisheries-independent surveys in this area not available at this time. As mentioned above, these groundfish surveys were designed to sample bottom dwelling species and capture only a small and erratic portion of the distribution of eulachon.

Threats

In 2008, the Eulachon BRT quantitatively ranked the severity of each of 16 potential threats to eulachon as either very low, low, moderate, high, or very high in four sub-areas (Klamath, Columbia, Fraser, and other British Columbia rivers) of the southern DPS of eulachon (see details in Gustafson et al. 2010). Results of this qualitative threats assessment indicated that climate change impacts on ocean conditions was the most serious threat to persistence of eulachon in all areas of the DPS. Climate change impacts on freshwater habitat and eulachon bycatch in offshore shrimp trawl fisheries were also ranked among the top four threats in all areas of the DPS. Dams and water diversions in the Klamath and Columbia rivers and predation impacts on the Fraser and British Columbia coastal river subpopulations filled out the last of the top four threats. Summaries of the impacts of these major threats to eulachon are presented in detail in the status review (Gustafson et al. 2010).

Critical habitat

NMFS (2011) has proposed to designate approximately 470 km (292 mi) of riverine and estuarine habitat occupied by the southern DPS of eulachon in California, Oregon, and Washington as critical spawning, incubation, and migratory habitat. However, due to lack of knowledge, critical nearshore and offshore ocean habitat has not been proposed. NMFS (2011, p. 522) stated that:

> Nearshore and offshore marine foraging habitat is essential for juvenile eulachon to survive and grow to adulthood, and for adults to survive and reproduce. At this time we have little information on eulachon distribution in marine waters and no information on where eulachon foraging habitat might occur. For these reasons, we are unable to identify any specific areas in marine waters that meet the definition of critical habitat under the ESA. Although we cannot presently identify any specific marine areas where foraging takes place, we will continue to gather information and will consider revising the designation in future rulemaking if new information supports doing so.

Fishery impacts

Recent groundfish fishery eulachon bycatch

Several recent reports (NWFSC 2008, 2009a, 2009b, 2010a, 2010b; Bellman et al. 2008, 2009, 2010, 2011) provide data on estimated bycatch of eulachon in U.S. West Coast commercial fisheries, which were derived from the West Coast Groundfish Observer Program (WCGOP) and the At-Sea Hake Observer Program (A-SHOP). Eulachon were observed as bycatch in the: (1) limited entry bottom trawl fishery; (2) at-sea Pacific hake/whiting mothership fishery; (3) at-sea Pacific hake/whiting tribal mothership fishery; (4) at-sea Pacific hake/whiting catcher-processor fishery; and (5) Oregon and California commercial shrimp trawl fishery (Bellman et al. 2011) (Table 14, Table 15, and Table 16). Bellman et al. (2011) provided estimated bycatch of eulachon from 2002–2009 as number of individual fish in the limited entry groundfish trawl and at-sea Pacific hake fisheries, and these data are copied from Bellman et al. (2011, p. 25) as Table 16.

Within the limited entry bottom trawl fishery, observer data (Table 14, Table 15, and Table 16), indicates that eulachon were rarely, or not all, encountered in the Washington and California portions of this fishery from 2002 to 2009. More eulachon encounters occurred in the Oregon portion of the limited entry bottom trawl fishery; however, total estimated bycatch from 2002 to 2009 was estimated at 1,009 total individual eulachon (Table 15). Bycatch in the Oregon limited entry bottom trawl fishery occurred in four of the eight observed years, with no bycatch occurring in 2004, 2005, 2006, or 2008 (Table 15). Bycatch in this fishery appears to be driven by both eulachon distribution and cyclic abundance. Peak yearly bycatch (819 eulachon) occurred in the Oregon portion of the limited entry bottom trawl fishery in 2002, which is also the year of recent peak abundance in the West Coast Vancouver Island offshore eulachon biomass index (Gustafson et al. 2010, their fig. 16). Landings in the Columbia River commercial fishery (Gustafson et al. 2010, their fig. 22) and estimates of eulachon larvae/m^3 in the Columbia River (Gustafson et al. 2010, their fig. 26) peaked in 2003, which is also consistent with high offshore abundance of eulachon during 2002.

The offshore fishery for Pacific hake occurs along the coasts of northern California, Oregon, and Washington from April–November. The fishery is conducted almost exclusively with mid-water trawls over bottom depths of 100–500 m. Bellman et al. (2011, p. 13) noted that eulachon in the at-sea hake groundfish fishery appear: "… to be encountered as bycatch in the catcher processor sector of the fishery more than other sectors [see Table 3, herein]. The highest eulachon bycatch in this mid-water trawl fishery was in 2006 with 145 individuals. In contrast, no eulachon were observed as bycatch in the bottom trawl fishery during 2006."

Based on the overall magnitude of bycatch in the limited entry trawl and at-sea hake fisheries, there is limited interaction with eulachon, especially in comparison to the commercial ocean shrimp trawl fishery. The Oregon commercial ocean shrimp trawl fishery had by far the largest amounts of eulachon bycatch (Bellman et al. 2011), and as this is not technically a groundfish fishery these data are discussed separately below in the "Other sources and levels of human caused mortality" section.

Probability of undocumented bycatch

It is uncertain if all observed smelt (family Osmeridae) bycatch in the limited entry bottom trawl and at-sea Pacific hake/whiting fisheries have always been identified to the species level. Due to sampling conditions and time constraints, it is likely that some portion of observed eulachon bycatch may have been recorded as "other non-groundfish," especially in the early years of the two observer programs. However, based on the reportage of eulachon as bycatch, starting in 2002 when the observer programs first began in the limited entry groundfish trawl and at-sea Pacific hake fisheries (Bellman et al 2011), and the overall limited interaction of these fisheries with eulachon, the likelihood that significant numbers of eulachon were included in the "other non-groundfish" category is small.

Table 14: Copied from Table 6 of Bellman et al. (2011). WCGOP coverage rates, number of eulachon observed, and eulachon bycatch ratios from limited entry bottom trawl vessels landing in Washington, Oregon, and California from 2002–2009. Coverage rates were computed as the proportion of FMP groundfish landings that were observed (see NWFSC 2010a for more details). Bycatch ratios were calculated for each state of landing and season as the observed catch of eulachon (in numbers) divided by the observed weight (mt) of retained groundfish (except Pacific hake). Winter season is January–April and November–December and summer season is May–October.

		Washington			Oregon			California		
Year	Season	Coverage rate	Number observed	Bycatch ratio	Coverag e rate	Number observed	Bycatch ratio	Coverag e rate	Number observed	Bycatch ratio
2002	winter	23%	0	0	14%	78	0.1289	12%	0	0
	summer	5%	0	0	15%	39	0.0735	13%	0	0
2003	winter	10%	0	0	19%	10	0.0111	11%	0	0
	summer	9%	0	0	12%	0	0	14%	0	0
2004	winter	39%	0	0	27%	0	0	33%	0	0
	summer	20%	0	0	19%	0	0	21%	1	0.0013
2005	winter	17%	0	0	26%	0	0	20%	0	0
	summer	21%	0	0	22%	0	0	19%	0	0
2006	winter	18%	0	0	20%	0	0	19%	0	0
	summer	23%	0	0	18%	0	0	20%	0	0
2007	winter	24%	0	0	14%	0	0	18%	0	0
	summer	7%	0	0	18%	13	0.0110	19%	0	0
2008	winter	2%	0	0	18%	0	0	18%	0	0
	summer	35%	0	0	24%	0	0	19%	0	0
2009	winter	26%	0	0	24%	0	0	19%	0	0
	summer	31%	0	0	24%	16	0.0084	18%	0	0

Table 15: Copied from Table 7 of Bellman et al. (2011). Total estimated seasonal bycatch of eulachon by state in the limited entry bottom trawl fishery from 2002–2009. Winter season is January–April and November–December and summer season is May–October.

		Estimated eulachon bycatch (number of individual fish)			
Year	**Season**	**Washington**	**Oregon**	**California**	**Total U.S. West Coast**
2002	winter	0	552	0	552
	summer	0	267	0	267
2003	winter	0	51	0	51
	summer	0	0	0	0
2004	winter	0	0	0	0
	summer	0	0	4	4
2005	winter	0	0	0	0
	summer	0	0	0	0
2006	winter	0	0	0	0
	summer	0	0	0	0
2007	winter	0	0	0	0
	summer	0	72	0	72
2008	winter	0	0	0	0
	summer	0	0	0	0
2009	winter	0	0	0	0
	summer	0	67	0	67

Table 16: Estimated yearly bycatch of eulachon (number of individual fish) in the limited entry bottom trawl fishery observed by the West Coast Groundfish Observer Program (WCGOP) and the At-Sea Hake Observer Program (A-SHOP) from 2002–2009. Data copied from Table 10 of Bellman et al. (2011, p. 25).

	Limited Entry Trawl			At-Sea Hake			
Year	**WA**	**OR**	**CA**	**Tribal Mothership**	**Non-tribal Mothership**	**Catcher Processor**	**Total eulachon**
2002	0	819	0	0	0	0	819
2003	0	51	0	0	0	0	51
2004	0	0	4	0	0	0	4
2005	0	0	0	0	0	0	0
2006	0	0	0	0	0	145	145
2007	0	72	0	0	4	6	82
2008	0	0	0	0	6	37	43
2009	0	67	0	32	6	30	135

Other Sources and Levels of Human Caused Mortality

The eulachon status review evaluated the potential roles that 16 current threats may play in the decline of the southern DPS of eulachon (Gustafson et al. 2010). The BRT ranked climate change impacts on ocean conditions as the most serious threat to persistence of eulachon in all four subareas of the DPS: Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers south of the Nass River. Climate change impacts on freshwater habitat and eulachon bycatch in offshore shrimp fisheries were also ranked in the top four threats in all subareas of the DPS. Dams and water diversions in the Klamath and Columbia rivers and predation in the Fraser and British Columbia coastal rivers filled out the last of the top four threats. Most human impacts on eulachon involve habitat alteration, and in the case of eulachon, these impacts have not been quantified, and comparisons of these threats with the impact of WCGF fisheries on eulachon are difficult. However, other fishery impacts are quantifiable, and where data are available, these sources of human caused mortality are reviewed.

Bycatch in shrimp trawl fisheries

Eulachon occur as bycatch in shrimp trawl fisheries off the coasts of Washington, Oregon, and California, (NWFSC 2008, 2009a, 2010b). Offshore trawl fisheries for ocean shrimp (*Pandalus jordani*) occur from the west coast of Vancouver Island to the U.S. West Coast off Cape Mendocino, California (Hannah and Jones 2003). *Pandalus jordani* is known as the ocean pink shrimp or smooth pink shrimp in Washington, simply pink shrimp in Oregon, and Pacific ocean shrimp in California. Herein we use the common name "ocean shrimp" in reference to *P. jordani,* as suggested by the American Fisheries Society (see Gustafson et al. 2010).

Prior to the mandated use of bycatch reduction devices (BRDs) in the ocean shrimp fishery, 32–61% of the total catch in the ocean shrimp fishery consisted of nonshrimp biomass, including various species of smelt (Hannah and Jones 2007). Beginning in 2003 in Washington, Oregon, and California, mandated use of BRDs in offshore shrimp trawl fisheries has substantially reduced bycatch of fin fish in these fisheries (Hannah and Jones 2007, Frimodig 2008). Reducing bycatch in this fishery has been an active field of research (Hannah et al. 1996, 2003, 2011; Hannah and Jones 2007; Frimodig 2008), and great progress has been made in reducing bycatch, particularly of larger-bodied fishes. As of 2005, following required implementation of BRDs, the total bycatch by weight had been reduced to about 7.5% of the total catch, and osmerid smelt bycatch was reduced to an estimated average of 0.73% of the total catch across all BRD types (Hannah and Jones 2007).

Based on WCGOP data in NWFSC (2008, its Table 3), observed eulachon bycatch in the Oregon and California ocean shrimp trawl fishery in the combined years of 2004, 2005, and 2007 was calculated to be 0.0005 and 0.0002, respectively. These bycatch ratios were calculated by dividing the observed total catch weight in mt of eulachon by the observed retained weight of ocean shrimp provided in NWFSC (2008, its Table 3). However, NWFSC (2008, its Table 6) provided a different estimate of the eulachon bycatch ratio for 2004, 2005, and 2007 in the

Oregon fishery, 0.0018 (SE = 0.0030), but a similar bycatch ratio to that estimated above for the California fishery; 0.0002 (SE = 0.0011).

Based on the above calculated bycatch ratios from NWFSC (2008, its Table 3), the estimated biomass of eulachon taken as bycatch in the Oregon and California ocean shrimp fisheries for the combined years 2004, 2005, and 2007 was calculated at about 10.9 and 0.43 mt, respectively—based on applying these ratios to the total ocean shrimp catches in those three years of 21,809 mt (48,080,482 lbs) in the Oregon trawl fishery and 2,136 mt (4,709,460 lbs) in the California trawl fishery. Similar application of the eulachon bycatch ratio in the Oregon trawl fishery of 0.0018 for these three years from NWFSC (2008, its Table 6) gave an estimated biomass of eulachon taken as bycatch of 39.3 mt.

NWFSC (2008, p. 24) calculated a eulachon bycatch rate of 0.0004 (SE = 0.0030) in the 2007 ocean shrimp trawl fishery north of 40°10′N latitude. Bellman et al. (2008, p. 38) used the ratio from NWFSC (2008) and total fleet landings of pink shrimp (mt, based on fish tickets) to calculate a bycatch of 4.7 mt of eulachon in the pink shrimp fishery north of 40°10′N latitude in 2007. The depressed abundance of the southern DPS of eulachon may be contributing to the above estimated levels of eulachon bycatch.

The eulachon bycatch rate in the ocean shrimp fishery with BRDs installed north of 40°10′N latitude was 0.0008 (SE = 0.0008) in 2008 and 0.0008 (SE = 0.0010) in 2009 (NWFSC 2009a, 2010b; Bellman et al. 2010). Given landings of ocean shrimp north of 40°10′N latitude (15,364 mt; NWFSC 2009a, its Table 1), there was a reported total bycatch in this fishery of 12.1 mt of eulachon in 2008 (Bellman et al. 2009, their Table 15). Bellman et al. (2010, their Table 7) estimated that the total bycatch of eulachon in the ocean shrimp trawl fishery north of 40°10'N latitude in 2009 was 10.8 mt.

Bellman et al. (2011) provided estimates of the number of individual eulachon caught in the Oregon and California ocean shrimp (aka, pink shrimp) trawl fishery as bycatch from 2004 to 2009 derived from WCGOP data (Table 17). Although "the WCGOP began coverage of Washington pink shrimp licenses in 2010, with the same criteria used for Oregon and California State pink shrimp coverage," these data are not yet available (Bellman et al. 2011). According to Bellman et al. (2011, p. 13):

> The largest amounts of eulachon bycatch were estimated in the Oregon pink shrimp trawl fishery. The largest estimate of eulachon bycatch occurred in 2009, when 861,888 individuals were estimated to have been caught [see Table **17** herein]. In 2009, the largest numbers of eulachon (63,174 individuals) were observed in the fishery, though fleet-wide landings were down slightly from the prior year [see Table **17** herein]. The lowest number of eulachon observed was in 2004 (11,290 individuals). … Fleet-wide pink shrimp landings in the California pink shrimp fishery are much lower than in the Oregon fishery [Table **17** herein] and eulachon bycatch is also lower. The range of eulachon bycatch in California extends from the highest number of eulachon individuals observed in 2008 (5,907 individuals), down to zero eulachon observed in 2005 and 2009.

The distribution and severity of eulachon bycatch encounters in the West Coast ocean shrimp (aka, pink shrimp) fishery were mapped in Bellman et al. (2011, their fig. 6). Furthermore, Bellman et al. (2011) showed that eulachon were most likely to be encountered as bycatch in shrimp tows observed by WCGOP fisheries from about 91–183 m in depth, although the greatest numbers of eulachon were caught between about 110 and 155 m depth.

Comparison of the three years (2007–2009) when estimates of the metric tonnage (Table 18) and the number of individual eulachon (Table 17) observed as bycatch in the ocean shrimp trawl fisheries north of 40°10´N latitude were available, indicates that the average weight of observed eulachon was 19.7, 23.9, and 10.3 g in 2007, 2008, and 2009, respectively. Thus, even though many more individual eulachon were observed in 2009 (over 63,000), than in 2008 (about 28,500), the weight of retained eulachon was larger in 2008 (0.68 mt) than in 2009 (0.65 mt) (Table 17 and Table 18). Eulachon at sea consist of a number of year classes (at least age 1+ and age 2+), and these data may indicate that a large portion of the eulachon bycatch observed in the ocean shrimp trawl fishery in 2009 consisted of the smaller age 1+ cohort than was present in 2008.

Degree of observer coverage

Unfortunately, no data are available yet on the level of eulachon bycatch in the Washington State ocean shrimp trawl fishery (Bellman et al. 2011). WCGOP began coverage of Washington pink shrimp licenses in 2010, but these data are not yet available. In Oregon and California, observer coverage in shrimp trawl fisheries has ranged from a low of 4% (2005) to a high of 7% (2007, 2009) of total ocean shrimp landings (Table 18). No ocean shrimp trawl fishery landings were observed in 2006.

Probability of undocumented eulachon bycatch in shrimp trawl fisheries

Due to sampling conditions and time constraints, not all smelt were identified to the species level in the Oregon and California ocean shrimp trawl fishery observer database in 2004, 2005, and 2007 (NWFSC 2008), and thus, a portion of the bycatch in these fisheries was recorded as "unidentified smelt." Observed biomass of unidentified smelt occurring as bycatch in the Oregon and California ocean shrimp trawl fisheries was reported as 5.6 and 0.02 mt, respectively, across the 3 years with observer data—2004, 2005, and 2007 (NWFSC 2008, its Table 3). Based on WCGOP data in NWFSC (2008, its Table 3), unidentified smelt bycatch in the Oregon and California ocean shrimp trawl fishery in the combined years of 2004, 2005, and 2007 was calculated to be 0.0032 and 0.0002, respectively. These bycatch ratios were calculated by dividing the observed total catch weight in mt of unidentified smelt by the observed retained weight of ocean shrimp. Based on the above calculated bycatch ratios from data in NWFSC (2008, its Table 3), the estimated biomass of unidentified smelt taken as bycatch in the Oregon and California ocean shrimp fisheries for the combined years 2004, 2005, and 2007 was calculated at about 69.8 and 0.4 mt, respectively—based on applying these ratios to the total ocean shrimp catches in those three combined years of 21,809 mt (48,080,482 lbs) in the Oregon trawl fishery and 2,136 mt (4,709,460 lbs) in the California trawl fishery. Based on the portion of the observed smelt bycatch biomass that was identified to species in the Oregon ocean shrimp fishery by the WCGOP (NWFSC 2008), the unidentified smelt biomass was likely about 60% eulachon. Thus, across the years 2004, 2005, and 2007, a sum total of the unidentified biomass of smelt that may have been eulachon was about 41.9 mt in the Oregon trawl fishery and 0.026 mt in the California trawl fishery.

Table 17: Bycatch of eulachon observed by the WCGOP from 2002–2009 in the Oregon and California pink shrimp trawl fisheries (modified from Bellman et al. [2011, their Table 8]). Ocean shrimp fisheries were not observed in 2006. Number of eulachon observed, observed pink shrimp landings, ratio of eulachon bycatch as reported in Bellman et al. (2011, their Table 8), ratio of eulachon bycatch as calculated from data in Bellman et al. (2011, their Table 8), and total pink shrimp landings (mt).

State Year	Number of eulachon observed	Observed pink shrimp landings (mt)	Calculated eulachon bycatch ratio (eulachon/shrimp)	Eulachon bycatch ratio reported in Bellman et al. (2011, Table 8)	Total pink shrimp landings (mt)	Calculated number of eulachon as bycatch	Number of eulachon as bycatch reported in Bellman et al. (2011, Table 10)
Oregon							
2004	11,290	427	26.4403	26.4692	5,537	146,400	146,560
2005	11,668	403	28.9529	28.9635	7,159	207,273	207,362
2006	--	--	--	--	5,532	--	--
2007	14,084	650	21.6677	21.6689	9,129	197,804	197,807
2008	22,633	672	33.6801	33.6566	11,576	389,880	389,604
2009	63,174	737	85.7178	85.7712	10,049	861,378	861,888
California							
2004	350	91	3.8462	3.8677	997	3,835	3,845
2005	0	22	0.0000	0.0000	861	0	0
2006	--	--	--	--	64	--	--
2007	977	23	42.4783	43.0944	289	12,276	12,456
2008	5,907	133	44.4135	44.3267	945	41,971	41,910
2009	0	130	0.0000	0.0000	1,184	0	0

Table 18: Estimated bycatch of eulachon (metric tons) in ocean shrimp trawl fisheries north of 40°10´N latitude observed by the West Coast Groundfish Observer Program (WCGOP) from 2004–2009. Ocean shrimp fisheries were not observed in 2006.

Year	Percent of total ocean shrimp landings observed	Eulachon observed (mt)	Ocean shrimp observed (mt)	Eulachon bycatch ratio (mt eulachon/mt shrimp)	SE of bycatch ratio	Total trawl fishery ocean shrimp landings (mt)	Calculated total eulachon bycatch (mt)	Reported total eulachon bycatch (mt)
2004 [a]	6%	N/A	533	N/A	N/A	8,706	N/A	N/A
2005 [a]	4%	N/A	448	N/A	N/A	10,687	N/A	N/A
2006	--	--	--	--	--	--	--	--
2007 [a]	7%	0.297	749	0.0004	0.0030	10,935	4.4	4.7 [d]
2004, 2005, 2007 [a]	--	0.842	1,766	0.0005	--	30,328	15.2	--
2008 [b]	6%	0.683	901	0.0008	0.0008	15,364	12.3	12.1 [e]
2009 [c]	7%	0.651	985	0.0008	0.0010	14,412	11.5	10.8 [f]

a – NWFSC (2008, its Tables 2, 3), b – NWFSC (2009a, its Table 2), c – NWFSC (2010b, its Table 2), d – Bellman et al. (2008, their Table 7), e – Bellman et al. (2009, their Table 15), f – Bellman et al. (2010, their Table 16).

Estimated future mortality based on projected changes from baseline (in effort and gear composition, as estimated above)

Beginning in 2003, in Washington, Oregon, and California, mandated use of BRDs in offshore shrimp trawl fisheries has substantially reduced bycatch of fin fish in these fisheries (Hannah and Jones 2007, Frimodig 2008). In December 2010, the Oregon Fish and Wildlife Commission mandated smaller spacing between the bars of bycatch reduction device (BRD) grates to reduce bycatch of eulachon in the Oregon ocean shrimp trawl fishery. The maximum bar spacing will be one-inch during the 2011 season (April 1 –October 31) and ¾-inches in the 2012 season (Hannah and Jones 2011; see Oregon Administrative Rules for Commercial Shellfish Fishery online at: [http://www.dfw.state.or.us/OARs/05.pdf]). Hannah and Jones (2011, p. 9) stated that their "data analysis showed that eulachon catch was about 16% less using the ¾" rigid-grate than with the 1.0 [inch] version, both by number and weight."

Collateral BRD mortality

Although data on survivability of BRDs by small pelagic fishes, such as eulachon, are scarce, many studies on other fishes indicate that "among some species groups, such as small-sized pelagic fish, mortality may be high" and "the smallest escapees often appear the most vulnerable" (Suuronen 2005, p. 13–14). Results of several studies have shown a direct relationship between length and survival of fish escaping trawl nets, either with or without deflecting grids (Sangster et al. 1996, Suuronen et al. 1996, Ingólfsson et al. 2007), indicating that smaller fish with their poorer swimming ability and endurance may be more likely to suffer greater injury and stress during their escape from trawl gear than larger fish (Broadhurst et al. 2006, Ingólfsson et al. 2007). It is difficult to evaluate the true effectiveness of BRDs or impact of the ocean shrimp trawl fisheries on eulachon mortality without knowing the survival rate of fish that are deflected by BRDs and escape the trawl net (Broadhurst 2000, Suuronen 2005, Broadhurst et al. 2006).

Commercial, recreational, and indigenous fisheries

Eulachon have been commercially harvested in the Columbia River since the late 1860s, and commercial landing records began in 1888 (see Gustafson et al. 2010). A large recreational dipnet fishery that occurs almost exclusively in Columbia River tributaries, and for which catch records are unavailable, has existed in concert with commercial fisheries (Gustafson et al. 2010). The eulachon commercial fishery in the Columbia River continued to operate in the 2009–2010 season. According to JCRMS (2011, p. 28):

> For the 2009–2010 season, the mainstem Columbia River was open (seven days a week) in December 2009, then scheduled to be open under Level One protocol during January 1 through March 31, 2010. … The 2010

> season consisted of two weekly fishing periods in Zones 1–5. The periods were seven hours each from 7 AM to 2 PM on Mondays and Thursdays. By late February, catch had been estimated at 3,600 pounds with peak landings occurring on January 21, and no catch had been reported since February 11. On March 8 the Compact met and closed the mainstem commercial fishery effective March 11, prior to the scheduled closure date of March 31. Cumulative landings and commercial CPUE indicated the eulachon return was smaller than previously expected. … No landings were made from commercial tributary fisheries in 2010.

According to JCRMS (2011, p. 29), "no catch or effort … [was] observed or reported" in mainstem Columbia River recreational eulachon fisheries during the 2010 season. JCRMS (2011, p. 29) also stated that:

> Under Level One fishery guidelines, the only Washington tributary open was the Cowlitz River. The season was restricted to Saturdays during the month of February from 7 AM−3 PM with a bag limit of ten pounds per person. … A pilot Cowlitz River angler survey was implemented during 2010; patterned after a study design last conducted in 1978. Recreational effort was poor due to low abundance. Harvest estimates based on the pilot creel program (from 239 smelt anglers interviewed) include a minimum of 140 pounds of smelt harvested from 714 hours fished.

No commercial or recreational fisheries opened in the Columbia River or its tributaries in the 2010–2011 season (JCRMS 2011).

Habitat and trophic effects

Smith and Saalfeld (1955, p. 12) stated that the only recognizable prey found in stomachs of adult eulachon captured off Washington in 1948 were abundant "remains of the cumacean, *Cumacea dawsoni*." Other authorities report that juvenile and adult eulachon eat primarily "euphausiids and copepods" (Hart 1973, p. 149) or "euphausiids, crustaceans, and cumaceans" (Scott and Crossman 1973, p. 323). Hay (2002, p. 100) stated that "eulachon stomachs from offshore waters indicate that [they] mainly consume the euphausiid *Thysanoessa spinifera*." Euphausiids (principally *Thysanoessa spiniferia* and *Euphausia pacifica*) appear to be a primary prey item of eulachon in the open ocean and are also eaten by many other competing species. Euphausiids are also known as krill. Since WCGF fisheries target relatively large, commercially valuable fish species, (see Chapter 2 Description of the Fisheries), prey items of eulachon, such as euphausiids, are not likely to be directly impacted by WCGF fisheries to any significant extent. Indirect trophic effects of WCGF fisheries are also expected to be minor and in fact may positively affect the abundance of euphausiids as prey for eulachon through removal of other predators on euphausiids (Appendix A).

Impact of WCGF fisheries on eulachon population growth rate/abundance

Due to a lack of data on population abundance and reproductive rates of eulachon, combined with the rarity of observing eulachon in the WCGF fisheries, it is not possible to quantify an estimated impact of WCGF fisheries on population growth rate of eulachon. However, the level of mortality in the WCGF (less than 1000 individuals annually) is very low compared to the probable total numerical abundance of the species (likely in the millions -- see discussion in Gustafson et al. 2010), and is therefore likely to be having at most a negligible effect on the southern DPS of eulachon. The impact of the WCGF is also very low compared to other fishery impacts, particularly the ocean shrimp trawl fisheries.

*Green sturgeon (*Acipenser medirostris*)*

General biology[12]

The green sturgeon is an anadromous, long-lived, and bottom-oriented (demersal) fish species in the family Acipenseridae. Green sturgeon do not mature until they are at least 15–17 years of age at a size of 1.4–2.2 m in length (Beamesderfer et al. 2007). The maximum age of adult green sturgeon is likely to range from 60–70 years, and adults may exceed 2 m in length and 90 kg in weight. This species is found along the west coast of Mexico, the United States, and Canada.

Sturgeon have skeletons composed mostly of cartilage and lack scales, instead possessing five rows of characteristic bony plates on their body called "scutes." On the underside of their flattened snouts are sensory barbels and a siphon-shaped, protrusible, toothless mouth. Recent genetic information suggests that green sturgeon in North America are taxonomically distinct from morphologically similar forms in Asia (Adams et al. 2007).

One of the most marine-oriented and widely distributed of the sturgeons, the green sturgeon spends most of its life in Pacific coastal marine and estuarine waters from Mexico to Alaska. Mature adults return to the mainstem of large rivers to spawn during the spring (peaking in May–June) every 2–4 years (Beamesderfer et al. 2007). Spawning areas have been documented in the Rogue, Klamath, Trinity, Sacramento, and Eel rivers (Adams et al. 2007). Green sturgeon fecundity (50,000–80,000 eggs; Van Eenennaam et al. 2001) is reportedly lower than other sturgeons, but the egg size is larger. Eggs are laid in turbulent areas of high velocity on the river bottom during the spring, which settle into the interstitial spaces between cobble and gravel (Adams et al. 2007). Eggs hatch after 6–8 days, and larval feeding begins 10–15 days post-hatch; larval development is completed within 45 days at 60–80 mm TL (Beamesderfer et al. 2007). After rearing in freshwater or the estuary of their natal river for one to four years, young green sturgeon move into coastal waters. While in the ocean and estuaries, green sturgeon feed on a variety of benthic invertebrates (including crangonid and callianasid shrimp, Dungeness crab, molluscs, and amphipods) and small fish, such as sand lances (*Ammodytes* spp.) and anchovies (Engraulidae) (Moyle 2002, Dumbauld et al. 2008).

Range, migratory behavior, and stock structure

Green sturgeon occur as two apparent stocks based on spawning locations—a northern distinct population segment (DPS) comprised of the Klamath and Rogue River population, and a southern DPS consisting of the Sacramento River population (Israel et

[12] Much of this section is taken directly from http://www.nmfs.noaa.gov/pr/species/fish/greensturgeon.htm

al. 2004, Adams et al. 2007). Genetic and acoustic tagging data indicate little migration between spawning areas of these DPSs, although they co-occur in non-natal marine and estuarine habitats to varying degrees (Israel et al. 2009, Lindley et al. 2011).

After migrating out of their natal rivers, subadult green sturgeon move between coastal waters and various estuaries along the West Coast between San Francisco Bay, CA and Grays Harbor, WA (Lindley et al. 2008, Lindley et al. 2011). Multiple rivers and estuaries are visited by dense aggregations of green sturgeon in summer months (Moser and Lindley 2007), and migration patterns differ among individuals within and among populations (Lindley et al. 2011). Mature adults enter their natal river in the spring and typically leave the river during the subsequent autumn when water temperatures drop below 10°C and flows increase (Erickson and Webb 2007); thereafter, they migrate among the coastal ocean and non-natal estuarine habitats before returning again to spawn 2–4 years later. Winter months are generally spent in the coastal ocean, with many green sturgeon migrating to northern waters in the fall; areas north of Vancouver Island are favored overwintering areas, with Queen Charlotte Sound and Hecate Strait likely destinations based on observed depth and temperature preferences and detections of acoustically-tagged green sturgeon at the northern end of Vancouver Island (Lindley et al. 2008, Nelson et al. 2010). Peak migration rates exceeded 50 km per day during the spring southward migration (Lindley et al. 2008).

Habitat use

Relatively little is known about how green sturgeon utilize habitats in the coastal ocean and in estuaries, or the purpose of their episodic aggregations there at certain times (Lindley et al. 2008, Lindley et al. 2011). While in the ocean, archival tagging indicates that green sturgeon occur between 0 and 200 m depths, but spend most of their time between 20–80 m in waters temperatures of 9.5–16.0°C (Nelson et al. 2010, Huff et al. in review). They are generally demersal but make occasional forays to surface waters, perhaps to assist their migration (Kelly et al. 2007). Recent telemetry data in coastal ocean habitats suggests that green sturgeon spent a longer duration in areas with high seafloor complexity, especially where a greater proportion of the substrate consists of boulders (Huff et al. in review). However, while in estuaries where green sturgeon feed over the bottom on benthic invertebrates (Dumbauld et al. 2008), they do not appear to use hard substrates. Preliminary data from feeding pit mapping surveys conducted in Willapa Bay, WA showed densities were highest over shallow intertidal mud flats, while harder substrates (e.g., gravel) had no pits (M. Moser, unpublished data). In rivers, sturgeon prefer deep pools and may hold there for up to nine-months, presumably for the purposes of spawning, feeding, and conserving/restoring energy (Israel et. al 2010).

Critical habitat

Critical habitat has been designated for the southern green sturgeon DPS (Federal Register: 74 FR 52300). In the coastal ocean, this designation covers waters shallower than 110 m from Monterey Bay, CA to the Canadian border, including the Strait of Juan de Fuca. Natal rivers and numerous estuaries along the West Coast (e.g., San Francisco

Bay, lower Columbia River estuary, Willapa Bay, and Grays Harbor) were also designated as critical habitat for the species.

Status[13]

NMFS received a petition in 2001 for the green sturgeon to be listed under the Endangered Species Act. In 2002, NMFS determined that the green sturgeon is comprised of two DPSs that qualify as species under the ESA, but that neither warranted listing as threatened or endangered. Uncertainties in the structure and status of both DPSs led NMFS to add them to the Species of Concern List.

The "not warranted" determination was challenged in 2003. NMFS produced an updated status review in 2005 and reaffirmed that the northern green sturgeon DPS only warranted listing on the Species of Concern List; however, it was proposed that the Southern DPS (defined as coastal and Central Valley populations, south of the Eel River in California) should be listed as threatened under the ESA (Adams et al. 2007). NMFS published a final rule in 2006 listing the Southern DPS as threatened (Federal Register: 71 FR 17757). In 2009, critical habitat was established for the Southern DPS (Federal Register: 74 FR 52300), with ESA take prohibitions to be applied under a 4(d) rule by 2010 (Federal Register: 75 FR 30714).

In Canada, the green sturgeon is designated as being a species of Special Concern (COSEWIC 2004).

Abundance and trend

To date, little population-level data have been collected for green sturgeon. In particular, there are no published abundance estimates for either the Northern or Southern green sturgeon DPS in any of the natal rivers based on survey data (Israel et al. in prep). As a result, efforts to estimate green sturgeon population size have had to rely on sub-optimal data with known potential biases, including monitoring designed for white sturgeon (*Acipenser transmontanus*) populations, harvest time series, or entrainment from water diversion and export facilities (Adams et al. 2007). Of these sources, only the water diversion data indicate a possible trend, suggesting green sturgeon abundance or recruitment has declined since 1986 in the Sacramento River (Adams et al. 2007). Long term population trends from fishery data (note: effort data is absent) indicate that the adult population in the Klamath River is fairly constant, with a few hundred spawning adults typically being harvested annually by tribal fisheries (Adams et al. 2007). Based on detections of tagged sturgeon in the marine environment during 2004, Lindley et al. (2008) estimated annual survival of tagged subadults and adults to be 0.83.

More recent genetic techniques and monitoring surveys are beginning to clarify questions about green sturgeon population size. Genetic data collected from outmigrating juvenile green sturgeon suggest that the number of adult green sturgeon in the upper Sacramento River (southern DPS) remains roughly constant, with between 10 and 28

---

[13] This section adapted from http://www.nmfs.noaa.gov/pr/species/fish/greensturgeon.htm

pairs breeding annually between 2002 and 2006 in river reaches above Red Bluff (Israel and May 2010). In rivers of the northern DPS, recently developed surveys using dual-frequency identification sonar have estimated spawning run sizes of a few hundred fish per year (E. Mora, unpublished data; Israel et al. in prep). Erickson et al. (unpublished) estimated run sizes ranging from 426 to 734 adult green sturgeon (point estimates) using mark-recapture methods in the same systems during the same year, (Israel et al. in prep). These studies suggest each population may be represented by less than 1,000 adults, considering spawning periodicity is 2–4 years (Beamesderfer et al. 2007). Furthermore, it is apparent that the abundance of mature green sturgeon in the southern DPS is much smaller than in the northern one (Adams et al. 2007). Nonetheless, carefully designed studies remain needed to provide absolute estimates of abundance for the species.

Threats (from Recovery Plan or listing documents)

Green sturgeon face a variety of threats in the freshwater, estuarine, and marine environments within which they move throughout their life history. Threats to this species include: reduction/loss of spawning areas, insufficient freshwater flow rates in spawning areas, contaminants (e.g., pesticides), harvest bycatch, potential poaching (e.g., for caviar), entrainment by water projects, influence of exotic species, small population size, impassable barriers, and elevated water temperatures (Adams et al. 2007). A principal factor in the decline of the Southern DPS has been the reduction of potential spawning habitat to a single area in the Sacramento River due to migration barriers (dams).

Fishery impacts

Historically, large numbers of green sturgeon were harvested by white sturgeon commercial and sport fisheries, which often considered them as bycatch due to their inferior meat quality and lower relative market value (Emmett et al. 1991, Adams et al. 2007). A relatively smaller part of the harvest occurred as bycatch from tribal gillnet salmon fisheries in the Columbia and Klamath Rivers. From 1985–2003, harvest came predominately from the Columbia River (51%), coastal trawl fisheries (28%), the Oregon fishery (8%), and the California Tribal fishery (8%) (Adams et al. 2007). The total average annual harvest of green sturgeon declined substantially from 6,494 fish in 1985–1989 to 1,072 fish in 2000–2003.

Recently enacted fishing regulations and conservation measures have reduced current fishery impacts to green sturgeon throughout its range (http://www.nmfs.noaa.gov/pr/species/fish/greensturgeon.htm). Various commercial and sport fisheries in California, Oregon, Washington (United States), and British Columbia (Canada) now ban retention of green sturgeon. Implementation of sturgeon fishing restrictions in Oregon and Washington and protective efforts put in place on the Klamath, Trinity, and Eel Rivers may offer protection to the Southern DPS.

Impacts, all fisheries

California, Oregon, Washington –The largest existing fisheries impact to green sturgeon is bycatch-related mortality from three coastal and estuarine fisheries: the coastal groundfish trawl fishery, white sturgeon commercial and sport fisheries, and Klamath Tribal salmon gillnet fisheries (Adams et al. 2007). The only fishery where green sturgeon are still legally retained in the U.S. is in Tribal gillnet fisheries in the Klamath River. Historical annual catches in the fishery appear to be of the same order of magnitude as spawning escapement, suggesting possibly unsustainable harvest rates. On the Klamath, Tribal harvest has accounted for 200–450 fish annually between 1985 and 2003, with no evidence of declining catches (Adams et al. 2007). However, the Yurok Tribe have recently adopted new regulations for their subsistence harvest that reduce impacts to green sturgeon (Israel et al. in prep).

Mexico, British Columbia –Green sturgeon are rarely encountered in coastal waters of Baja California, Mexico, and fishery impacts in Mexican waters are likely negligible.

Canada currently bars retention of green sturgeon in all fisheries, although they are frequently encountered in coastal bottom trawl fisheries off the west coast of Vancouver Island and may have been specifically targeted in past decades (COSEWIC 2004).

Alaska –Observers have only rarely encountered green sturgeon as bycatch in trawl fisheries in the Bering Sea (Colway and Stevenson 2007).

Impacts, WCGF fisheries

Recently published summaries of bycatch estimates from U.S. West Coast groundfish fisheries provide guidance on the scale of impacts from 2002–2009 (Adams et al. 2007, Bellman et al. 2011). On average, 331 green sturgeon are estimated to have been caught per year from 2002–2009. The largest green sturgeon bycatch estimates occurred in 2006, when 793 individuals were estimated from the fishery; in comparison, an estimated 89 fish were caught in 2009 (Table 19).

The most important impact of WCGF fisheries appears to be benthic trawl fisheries occurring on the inner shelf. Most of the green sturgeon bycatch (annual average of 77%, 2002–2009) occurred in the limited entry sector of the California halibut (*Paralichthys californicus*) commercial trawl fishery, which primarily takes place at depths of <60 m in fishing grounds adjacent to San Francisco Bay, California (Bellman et al. 2011) (Table 19). By comparison, green sturgeon bycatch in the at-sea hake fishery is very low, with only three green sturgeon recorded by the observer program from 2002–2009. The depth distribution of tows encountering green sturgeon bycatch (2002–2009, all fisheries combined) indicates most sturgeon were caught in depths ≤10 m, but may be encountered in tows ranging from 0 to 130 m depth (Bellman et al. 2011).

The length frequency distribution of green sturgeon caught in the California halibut fishery from 2007 through April 2010 showed most individuals range in size from 80–110 cm total length (Bellman et al. 2011), which corresponds to ages of less than 15 years based on published age-length relationships (Beamesderfer et al. 2007). Because trawl bycatch is composed of smaller individuals, the data suggests larger adults are either not present in these areas or not vulnerable to capture by these fishing gear. It is likely that many of the green sturgeon collected as bycatch in the California halibut trawl fishery are from the Southern DPS, based on the estuarine distribution of green sturgeon populations (Lindley et al. 2011) and the fishery's primary trawl grounds (Bellman et al. 2011).

Green sturgeon bycatch estimates do not include any correction for discard survivorship, which is not currently available. However, preliminary research indicates green sturgeon may be susceptible to some level of discard mortality, particularly when encounters with fishing gear occur in higher temperature environments and last for longer periods of time (Bellman et al. 2011). It is in principle possible to estimate these rates from a tagging program, using a combination of traditional reward tags and pop-off archival tags (applied to discards), but such studies have not yet been conducted.

Given the poorly known size of green sturgeon populations and bycatch survival rates, it is not possible to assess the WCGF fishery impact on the species.

Table 19: Estimated bycatch of green sturgeon (number of individual fish) in all U.S. West Coast fisheries observed by the West Coast Groundfish Observer Program (WCGOP) and the At-Sea Hake Observer Program (A-SHOP) from 2002–2009. Open access CA halibut fisheries were not observed in 2002 or 2006 (derived from Table 5 in Bellman et al. 2011).

	WCGOP					**A-SHOP**	
	Limited Entry Trawl			**CA Halibut**		**At-Sea Hake**	**Green Sturgeon Total**
Year	**WA**	**OR**	**CA**	**Limited Entry**	**Open Access**		
2002	19	13	0	19	--	0	51
2003	0	0	0	345	15	0	360
2004	0	10	4	194	65	0	273
2005	4	4	0	504	270	1	783
2006	0	5	0	786	--	2	793
2007	0	5	0	102	0	0	107
2008	0	0	0	188	0	0	188
2009	0	37	5	47	0	0	89

* A value is (--) when the fishery/strata was not observed as a whole. Note: Bycatch refers to number of sturgeon caught and released (discarded) at sea; total mortality is not estimated because discard survivorship rates remain unmeasured.

Habitat and trophic effects

WCGF bottom trawl fisheries are likely to have some impact on both the habitat and prey of green sturgeon. The diet of green sturgeon in the ocean is poorly known, but it is likely that they prey upon demersal fish (sand lance are a known diet item) captured in these fisheries. While green sturgeon seem to prefer high-relief, complex, benthic habitats at certain times and places, it is not clear what features of these habitats they are responding to and how dependant they are upon them (i.e., is it the boulders themselves or biota associated with the boulders?) (Huff et al. in review). Recent gear restrictions (i.e., footrope limits) and landing limits have been effective in protecting rocky habitats along the Pacific Coast from trawl fishing impacts by shifting fishing effort away from these areas (Bellman et al. 2005). Therefore, management efforts directed at protecting the rocky habitat of depleted rockfish (*Sebastes* spp.) may have accrued some additional benefits to green sturgeon in the ocean. These habitat and trophic effects are difficult to quantify more accurately, however, until more definitive information is known about the marine habitat preferences and diets of green sturgeon.

Impact of WCGF fisheries on population growth rate

It is currently not possible to assess the impact of WCGF fisheries on the population growth rate of green sturgeon from available data. The most likely impacts would occur through discard-related mortality of green sturgeon captured in bottom trawl fisheries, yet survival rate of discarded green sturgeon is unknown (although possibly high given their armor, relatively shallow distribution, and open swim bladder). These uncertainties, combined with unknown green sturgeon population size, make it difficult to assess the current impact of the WCGF fishery on the population growth rate.

Chapter 6: Marine turtles

*Leatherback turtle (*Dermochelys coriacea*)*

General biology[14]

The leatherback is the largest, deepest diving, and most migratory and wide ranging of all sea turtles. Reaching 4 to 6 feet in length and 500 to 1,500 pounds in weight, its shell consists of small bones covered by firm, rubbery skin with seven longitudinal keels. Leatherbacks are black with varying degrees of pale spotting, including a pink spot on the adult head. A tooth-like cusp sits on each side of the upper jaw, while the lower jaw is hooked. The paddle-like, clawless limbs are black with white margins and pale spots.

Female leatherbacks lay clutches of approximately 80 eggs in the sand on tropical beaches, several times during a nesting season. Leatherback hatchlings emerge from the nest after about two-months

Unlike other sea turtles that feed on hard-bodied prey, leatherbacks do not possess crushing chewing plates (Pritchard 1971). Instead, their pointed tooth-like cusps and sharp edged jaws work well for their diet of soft-bodied pelagic prey. Backward-pointing spines located in their mouth also masticate the soft prey.

Range, migration and foraging

Adult leatherback sea turtles enjoy the most extensive range of any living reptile (71EN to 47ES; Pritchard and Trebbau 1984). The seasonal presence of adult females at major eastern and western Pacific rookeries reveals migration between nesting and non-nesting areas, characteristic of Pacific stocks (Benson et al. 2007; Benson et al. 2011). Although the exact location and timing of migration is still being documented, their eastern Pacific migratory corridors exist along the western seaboards of the United States

---

[14] This information is summarized from:

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1992. Recovery plan for leatherback turtles (*Dermochelys coriacea*) in the U.S. Caribbean, Atlantic, and Gulf of Mexico. National Marine Fisheries Service, Washington, D.C. 65pp.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1998. Recovery plan for U.S. Pacific populations of the leatherback turtle (*Dermochelys coriacea*). National Marine Fisheries Service, Silver Spring, MD. 65pp.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 2007. Leatherback sea turtle (*Dermochelys coriacea*). 5-Year review: Summary and Evaluation. Available from: http://www.nmfs.noaa.gov/pr/pdfs/species/leatherback_5yearreview.pdf and Mexico, as well as transpacific migrations from Western Pacific nesting beaches (Benson et al. 2007, Benson et al. 2011).

The leatherback inhabits the continental shelf and pelagic environments. While foraging in the insular Pacific, individuals also occur in deep water near prominent archipelagoes. Leatherback distribution correlates with the presence of macroplanktonic prey. Stomach content analyses have indicated that leatherbacks feed on medusa, siphonophores, and salpae in temperate and boreal latitudes. Eisenberg and Frazier (1983) observed an adult feeding on the jellyfish Aurelia off the coast of Washington State.

It is now understood that leatherbacks undertake trans-Pacific migration (Figure 15; Benson et al. 2011). Morreale et al. (1994), using satellite telemetry, likewise reported that nesting cohorts appear to share identical post-nesting migrational pathways. However, Benson et al. (2011) also demonstrated that leatherbacks do not just drift in instinctive obedience to migratory impulse, but navigate seasonally and with temperature and current, visiting eddies, boundaries, and blooms in order to forage.

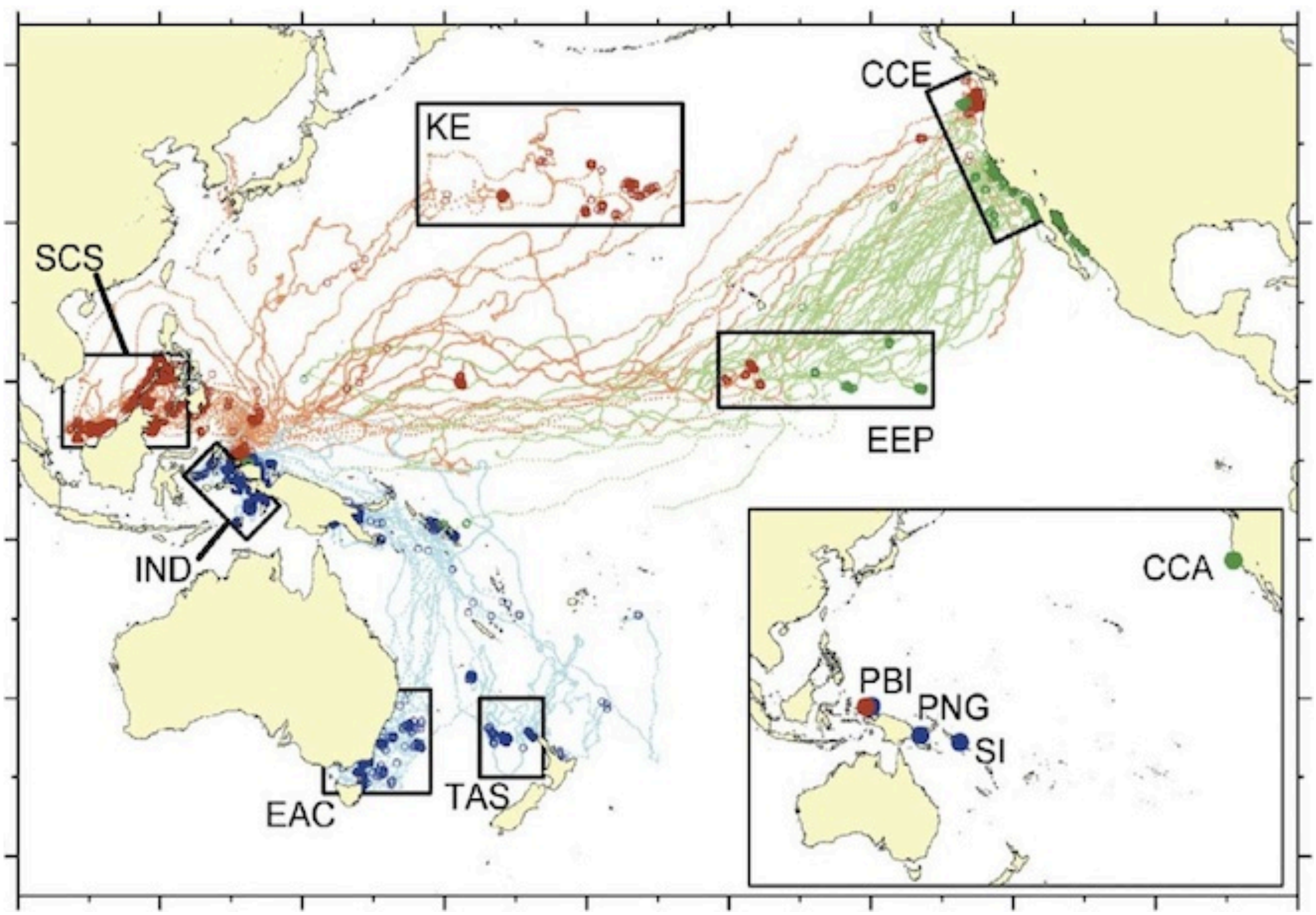


Figure 15: Between 2000 and 2007, Benson et al. (2011) attached GPS transmitters to 126 leatherbacks nesting in Indonesia, the Solomon Islands and Papua New Guinea. The colored lines indicate transpacific migration from their nesting grounds to the waters adjacent to the West Coast of North America. Reproduced from Benson et al. (2011).

Nesting Grounds

Historically, some of the largest nesting populations of leatherback turtles in the world bordered the Pacific Ocean, but no nesting occurs on Pacific beaches under U.S. jurisdiction. Nesting is widely reported from the western Pacific, including China, Southeast Asia, Indonesia, and Australia (Benson et al. 2007; Benson et al. 2011). Virtually all of the leatherbacks encountered on the West Coast of the U.S. originated in the western Pacific (Figure 15; Benson et al. 2007; Benson et al. 2011).

NMFS & USFWS (2007) recently summarized the abundance leatherback turtles nesting in the eastern and western Pacific. In the western Pacific (the apparent source of virtually all of the turtles off the U.S. West Coast), there do not appear to be sufficient data to estimate long-term trends. In the eastern Pacific (Costa Rica, Mexico), there appear to have been substantial declines in nesting abundance since the 1980s (see discussion in NMFS & USFWS 2007).

Habitat use

Leatherbacks are often described as a pelagic species; however, it is becoming increasingly evident that they aggregate in productive coastal areas to forage on preferred jellyfish prey (*scyphomedusae)* (Houghton et al., 2006; Benson et al., 2007; Witt et al., 2007). While their range spans the entire Pacific, occupation of the California Current is highly seasonal. Most of our current knowledge of leatherback turtle use of the California Current comes from recent and ongoing telemetry studies, aerial surveys, and ship-based research conducted primarily in the near-shore areas off central California. The telemetry work from Benson et al. (2011) has documented transpacific migrations between the western tropical Pacific and the California Current, which helps to identify migratory corridors (Figure 15).

Likewise, recent satellite-tracking studies at nesting beaches in Costa Rica and Mexico indicate that female turtles journey into pelagic waters after the nesting season ends. Leatherbacks were regularly captured in mid-Pacific waters by pelagic driftnet fisheries (Wetherall et al. 1993). Mortality and survival statistics are unavailable, and age-at-maturity and longevity have not been determined. Comprehensive discussions of the early pelagic stage of sea turtle development (the "lost year"), which include sightings of post-hatchling stage loggerhead, green, and hawksbill turtles associated with Sargassum weed and convergence debris, do not mention sightings of young *Dermochely*s.

Critical habitat

The USFWS initially designated critical habitat for leatherbacks on 26 September 1978 (43 FR 43688). The critical habitat area consisted of a strip of land 0.2 miles (0.32 kilometers) wide (from mean high tide inland) at Sandy Point Beach on the western end of the island of St. Croix in the U.S. Virgin Islands. On 23 March 1979, NMFS designated the marine waters adjacent to Sandy Point Beach as critical habitat from the hundred fathom (182.9 meters) curve shoreward to the level of mean high tide (44 FR 17710). In 2010, NMFS proposed revising the current critical habitat for the leatherback sea turtle by designating additional areas within the Pacific Ocean (Figure 16). Specific areas proposed for designation included two adjacent marine areas totaling approximately 46,100 square miles (119,400 square km) stretching along the California coast from Point Arena to Point Vincente, and one 24,500 square mile (63,455 square km) marine area stretching from Cape Flattery, Washington to the Umpqua River (Winchester Bay), Oregon east of a line approximating the 2,000 meter depth contour. The areas proposed for designation comprised approximately 70,600 square miles (182,854 square km) of marine habitat (Figure 16). Other Pacific waters within the U.S. Exclusive Economic Zone (EEZ) were evaluated based on the geographical area occupied by the species, but it was decided to exclude those areas from the critical habitat designation.

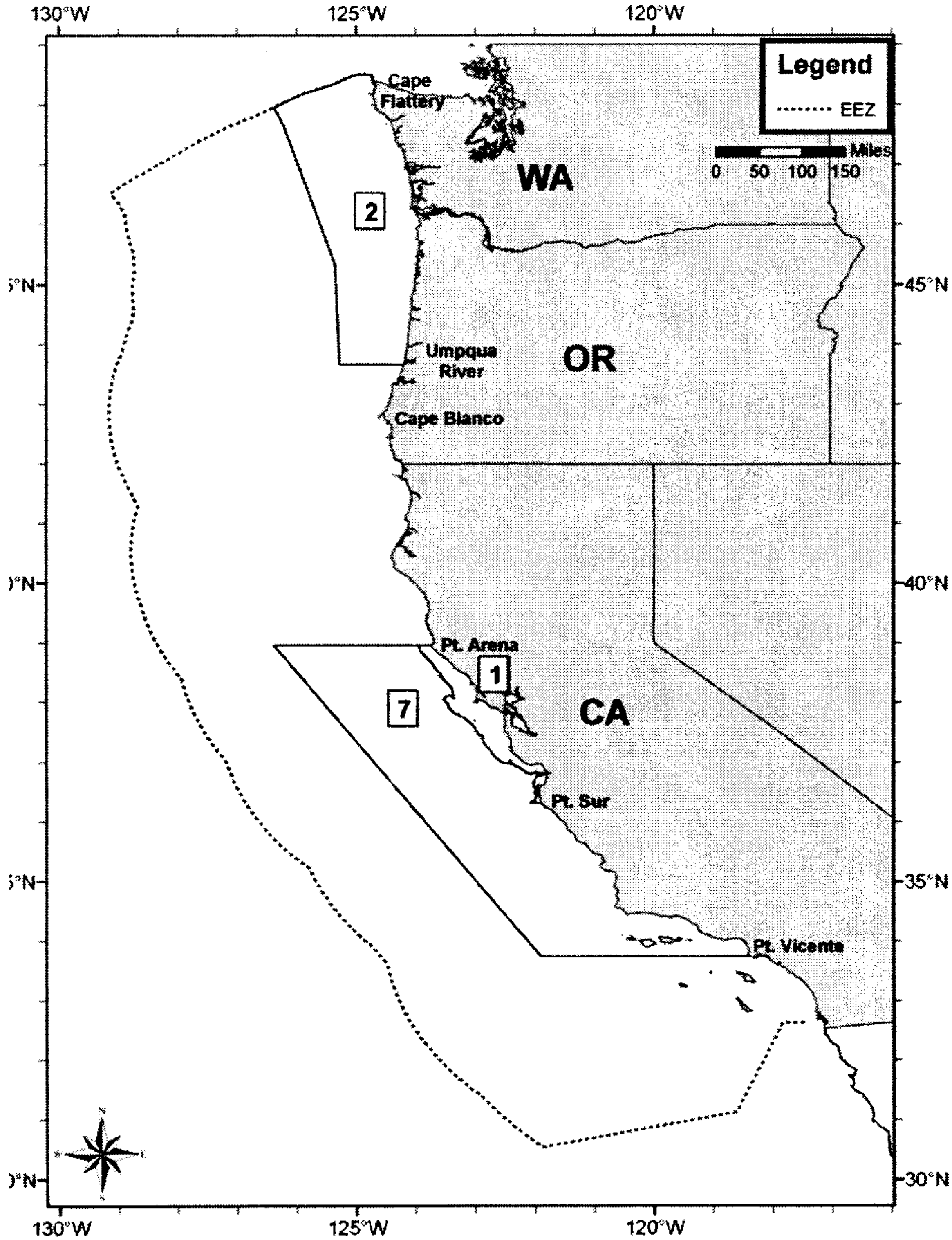


Figure 16: Map of proposed critical habitat for leatherback sea turtles (Source FR Doc. E9–31310 Filed 12–31–09)

Status

The leatherback sea turtle was listed as endangered throughout its range on 2 June 1970 under the U.S. Endangered Species Act (ESA). Similarly, the species is classified as Endangered in the International Union for Conservation of Nature and Natural Resources (IUCN) Red Data Book, where taxa so classified are considered to be "in danger of extinction and whose survival is unlikely if the causal factors continue operating". Leatherbacks are included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), a designation that effectively bans trade in specimens or products except by special permit. Such a permit must show that the trade is not detrimental to the survival of the species and is not primarily for commercial purposes. There is no commercial trade in leatherback sea turtles or their parts or products at the present time.

Abundance and trend

Leatherbacks are seriously declining at all major Pacific basin rookeries (Bhaskar 1985; Betz and Welch 1992; Chua 1988; Limpus, 1995), largely as a result of intensive egg collection and fishery bycatch. Population declines have also been reported in India, Sri Lanka, and Thailand (Ross and Barwani 1982).

In the case of Mexiquillo, Michoacán, an estimated 4,796 nests were laid on 4.5 km of beach in 1986–1987, and approximately 1,074 nests were laid in 1989–1990 (L. Sarti M., UNAM, unpubl. data). The aerial survey data of Sarti et al. (1996) indicate that a geographic shift in nesting is unlikely. Leatherbacks are occasionally sighted at sea, with a growing database documenting their incidental catch in coastal and pelagic fisheries.

Threats

Leatherback turtles face a variety of threats, depending on the region in which they occur. On the U.S. West Coast, the primary turtle threat consists of incidental take in fisheries. Incidental catch poses a threat in pelagic foraging and transit areas, and the coastal feeding grounds and migratory corridors that probably exist along the West Coast of the United States and south into Mexico, and between the western Pacific and the California current. Entanglement and ingestion of marine debris, including old abandoned nets, continues to pose a threat to leatherbacks.

Fishery impacts

In designating critical habitat, NMFS identified two primary constituent elements (PCEs) essential for the conservation of leatherbacks in marine waters off the U.S. West Coast: (1) occurrence of prey species, primarily *scyphomedusae* of the order Semaeostomeae (Chrysaora, Aurelia, Phacellophora, and Cyanea), of sufficient condition, distribution, diversity, and abundance; (2) Migratory pathway conditions to allow for safe and timely passage and access to/from/within high use foraging areas. When evaluating the second identified PCE—migratory pathway conditions or passage—

NMFS considered the type of activities that could affect or impede the passage of a leatherback turtle. After reviewing several potential types of impediments, NMFS determined that only permanent or long-term structures that alter the habitat would be considered as having potential effects on passage. Given this determination, NMFS did not consider fishing gear or vessel traffic as potential threats to passage.

California, Oregon, Washington

From 2002 to 2009, the Observer Program documented one incident of leatherback turtle being taken in fishing gear in the North Pacific (Jannot et al., 2011). This resulted in a single leatherback turtle mortality during the reporting period. However, the very low observer coverage of this fishery did not allow for accurate estimation of the fleetwide mortality rate on the basis of this single take (Jannot et al. 2011). The WCGF fisheries clearly overlap with the foraging distribution of leatherback turtles (Figure 17, Figure **18**, and Figure **19**), so there is clearly some potential for impacts due to ship strikes or entanglement (Figure 17, Figure **18**, and Figure **19**).

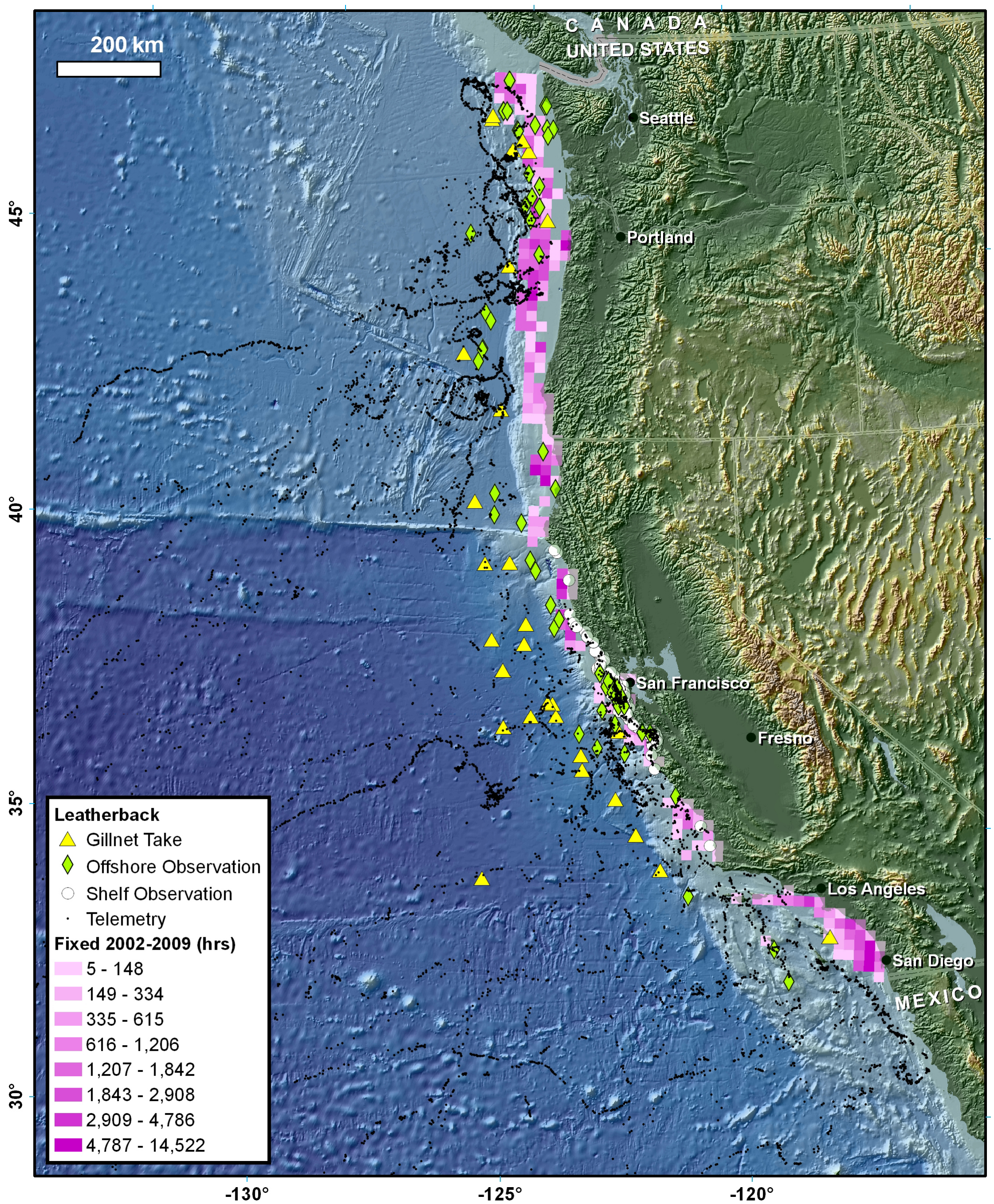


Figure 17: Leatherback vs Fixed Gear. Pink grid (Fixed 2002–2009 [hours]): Cumulative number of hours the fixed gear fishing fleet (see Feist et al. 2010 in Appendix B for details) had gear deployed in the water, expressed per gridcell (20 km on a side) from the years 2002–2009. Fixed gear types represented include historic longline, vertical hook and line, other hook and line, pot, and longline (fixed hook), longline (snap gear). Yellow triangles (Gillnet Take) from leatherback sea turtle bycatch locations for the DGN (gillnet) fishery. Green diamonds (Offshore Observation) and white circles (Shelf Observation) from NOAA sighting data and sighting data from platforms of opportunity for leatherback sea turtles. Black dots (Telemetry) from satellite telemetry point locations from 18 leatherback sea turtles. Turtle location information reproduced from NMFS et al. (2009).

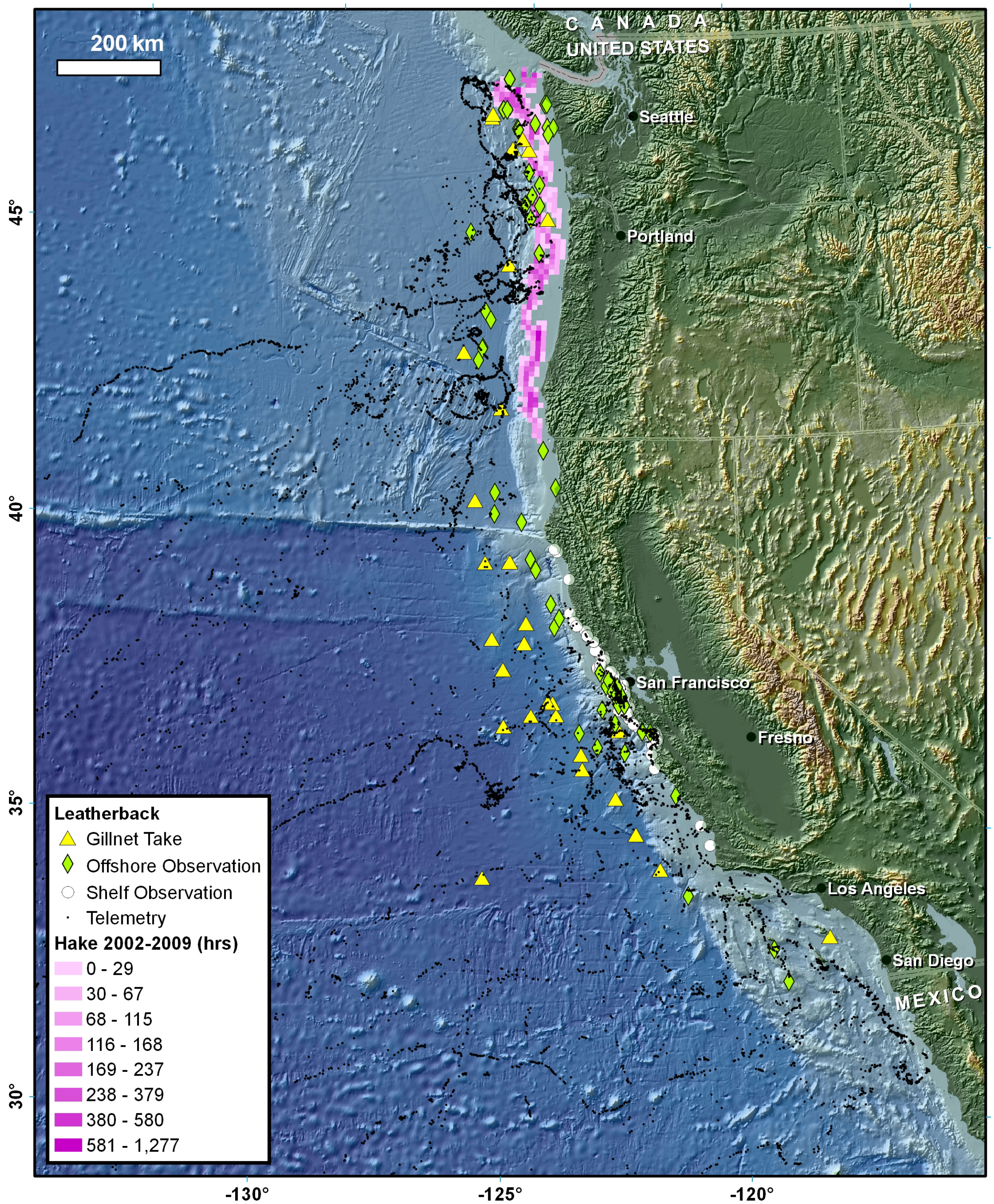


Figure 18: Leatherback vs Hake Fishery. Pink grid (Fixed 2002–2009 [hours]): Cumulative number of hours the at-sea hake fleet (see Feist et al. (2010) in Appendix B for details) had gear deployed in the water, expressed per gridcell (10 km on a side) from the years 2002–2009. Yellow triangles (Gillnet Take) from leatherback sea turtle bycatch locations for the DGN (gillnet) fishery. Green diamonds (Offshore Observation) and white circles (Shelf Observation) from NOAA sighting data and sighting data from platforms of opportunity for leatherback sea turtles. Black dots (Telemetry) from satellite telemetry

point locations from 18 leatherback sea turtles. Turtle location information reproduced from NMFS et al. (2009).

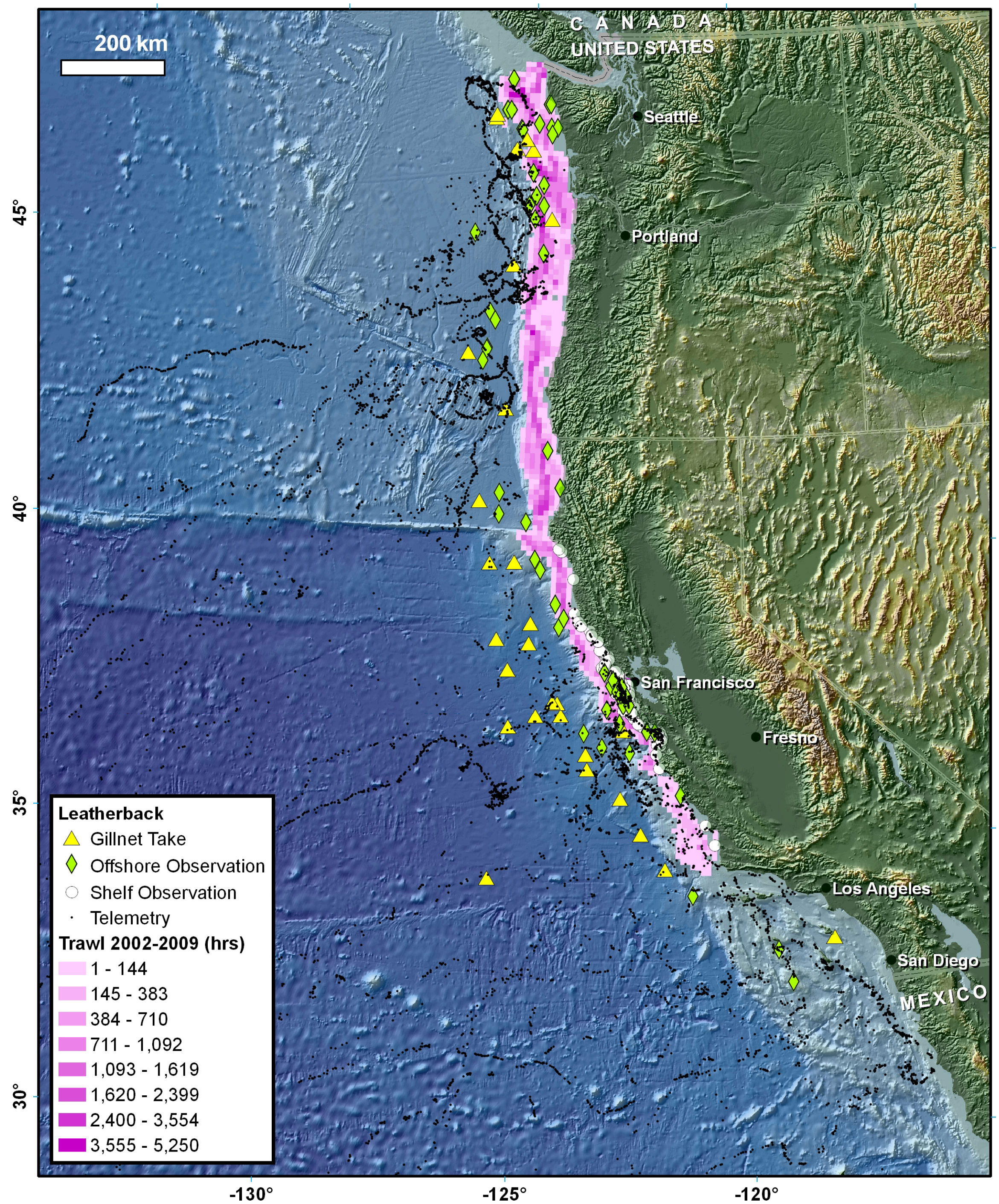


Figure 19: Leatherback vs Trawl Fishery. Pink grid (Fixed 2002–2009 [hours]): Cumulative number of hours the bottom trawl fleet (see Feist et al. (2010) in Appendix B for details) had gear deployed in the water, expressed per gridcell (10 km on a side) from the years 2002–2009. Yellow triangles (Gillnet Take) from leatherback sea turtle bycatch locations for the DGN (gillnet) fishery. Green diamonds (Offshore Observation) and white circles (Shelf Observation) from NOAA sighting data and sighting data from platforms of

opportunity for leatherback sea turtles. Black dots (Telemetry) from satellite telemetry point locations from 18 leatherback sea turtles. Turtle location information reproduced from NMFS et al. (2009).

Habitat and trophic effects

WCGF fisheries target relatively large, commercially valuable fish species, including rockfish, hake, and various mid-water and bottom fish (see Chapter 2 Description of the Fisheries). Leatherback turtles feed primarily on jellyfishes, which are not impacted by the WCGF fisheries to any significant extent. Indirect trophic effects of the WCGF fisheries are also expected to be minor.

Impact of WCGF fisheries on population growth rate

Because there is some overlap between the WCGF fisheries and leatherback turtle foraging distribution, the fishery may have some potential to impact leatherback turtles through bycatch or possibly ship strikes. However, despite the spatial and temporal overlap between the turtle distribution and the fishery, there has been only a single observed mortality due to fishing gear off the West Coast since 2000. For those sectors of the fishery with relatively high observer coverage (see Chapter 2 Description of the Fisheries) and no observed bycatch, we can be confident that the impacts on leatherback turtles of those sectors is low. However, the single reported take occurred in a sector (non-nearshore open acesss fixed gear) with very low observer coverage (1–9% from 2002 to 2009; Appendix H in Jannot et al. 2011). The abundance trend of the western Pacific population that forages off the U.S. West Coast does not appear to be known accurately. The lack of both accurate data on population trend and accurate estimates of take in some components of the fishery makes accurate estimation of effects impossible at this time.

*Green turtle (*Chelonia mydas*), Olive ridley turtle (*Lepidochelys olivacea*), Loggerhead turtle (*Carretta carretta*)*

Green turtles nest in numerous tropical beaches worldwide (see Figure 1 of NMFS & USFWS 2007b) and forage in coastal areas, but they are also found in the open ocean. The endangered Pacific Mexico breeding population forages primarily from the U.S.-Mexico border south along the west coast of Mexico. Green turtles are observed off the California coast during the summer, and a small population exists year-round in San Diego Bay.[15] However, their foraging areas are primarily south of the U.S.-Mexico border (NMFS & USFWS 2007b), and they have not been observed as bycatch in WCGF fisheries (Jannot et al. 2011). The generally low spatial overlap of the species with these fisheries, combined with the lack of any observed bycatch, suggests that these fisheries are unlikely to impact the species.

The olive ridley is another primarily tropical species that is rarely observed off the U.S. West Coast and has not been observed as bycatch in WCGF Fisheries (NMFS & USFWS 2007; Jannot et al. 2011). The generally low spatial overlap of the species with these fisheries, combined with the lack of any observed bycatch, suggests that these fisheries are unlikely to impact the species.

On 22 September 2011, NMFS adopted a Final Rule designating nine loggerhead DPSs worldwide (76 CFR 58868). A separate DPS was designated for the North Pacific Ocean, which is the subject of this assessment. The nesting habitat for this DPS occurs primarily in Japan, where trends in nesting females have generally been declining (Conant et al. 2009). Fisheries in Baja California, Mexico, and Japan take large numbers of loggerhead turtles annually, and they are considered a significant threat to the species (NMFS 2009). However, the species is rarely observed along the U.S. West Coast and has not been observed as bycatch in WCGF fisheries (Jannot et al. 2011). Some bycatch has occurred in California gill net fisheries near the U.S.-Mexico border (Julian and Beeson 1998; Jeffrey Seminoff personal communication), and it is possible that the fixed gear portion of the WCGF fisheries could encounter loggerhead turtles in that area (Figure **2**). However, considering the generally low spatial overlap between the species and the WCGF and the lack of observed take in these fisheries, it appears that any impacts are likely to be minor.

[15] http://swfsc.noaa.gov/textblock.aspx?Division=PRD&ParentMenuId=212&id=4378

Chapter 7: Seabirds

*Short-tailed albatross (*Phoebastria albatrus*)*

General biology[16]

Short-tailed albatrosses are large, pelagic seabirds with long, narrow wings adapted for soaring just above the water surface. Fledged juveniles are dark brown-black, but they soon develop pale bills and legs. Their white heads develop a yellow-gold crown and nape over several years. Their bills are large and pink with a bluish hooked tip, a conspicuous thin black line around the base, and, as in other Procellariiformes (tube-nosed marine birds), conspicuous external nostrils. They are the largest of the three species of North Pacific albatross, with a body length of 33–37 in (84–94 cm) and a wingspan of 84–90 in (213–229 cm) (Harrison 1985). Short-tailed albatross adults weigh 3.7–6.6 kg (USFWS 2008).

Birds breed at 5–6 years of age; a colonial, annually breeding species, individuals arrive on Torishima Island (main breeding colony) in Japan in October, but 25% of breeding-age adults may forego breeding in a given year. A single egg is laid in late October to late November (Austin 1949), and both parents incubate over a 64–65 day period. Hatching occurs from late December through January (Hasegawa and DeGange 1982). Chicks begin to fledge in late May–early June (Austin 1949), when adults begin abandoning the colony site (Hasegawa and DeGange 1982, Suryan et al. 2008). There is no detailed information on timing of breeding on the other colonies.

Short-tailed albatross are central place foragers and bring food back to nestlings after surface feeding on primarily squid (especially the Japanese common squid [*Todarodes pacificus*]), shrimp, fish (including bonitos [*Sarda* sp.], flying fishes [Exocoetidae] and sardines [Clupeidae]), flying fish eggs, and other crustaceans (Hasegawa and DeGange 1982, Tickell 1975, Tickell 2000). There is little information on non-breeding diet, but it is thought that squids, crustaceans, and fishes are important prey (Hasegawa and DeGange 1982).

Range, migratory behavior, and stock structure

Breeding Range

The short-tailed albatross once ranged throughout most of the North Pacific Ocean and Bering Sea (Figure **20**). A recent discovery of a fossil breeding site on Bermuda confirms that the species also formerly nested in the North Atlantic during the

[16] Most of the material in this section is summarized directly from: U.S. Fish and Wildlife Service. 2008. Short-tailed Albatross Recovery Plan. Anchorage, AK, 105 pp.

mid-Pleistocene (420–362 thousand years ago; Olson and Hearty, 2003). In the North Pacific, short-tailed albatross historically bred on few colonies from the Izu, Bonin, Daito, and Senkaku, western volcanic groups in Japan, and Agincourt Island and the Pescadore Islands in Taiwan (Hasegawa 1984). Of the known historical breeding colonies, only two are now active. The vast majority (80–85%) of the known breeding short-tailed albatross nest on colonies on Torishima Island (Izu group), which is an active volcano. The remaining known breeding birds nest on Minami-kojima (Senkaku Islands), whose ownership is under dispute among Japan, China, and Taiwan.

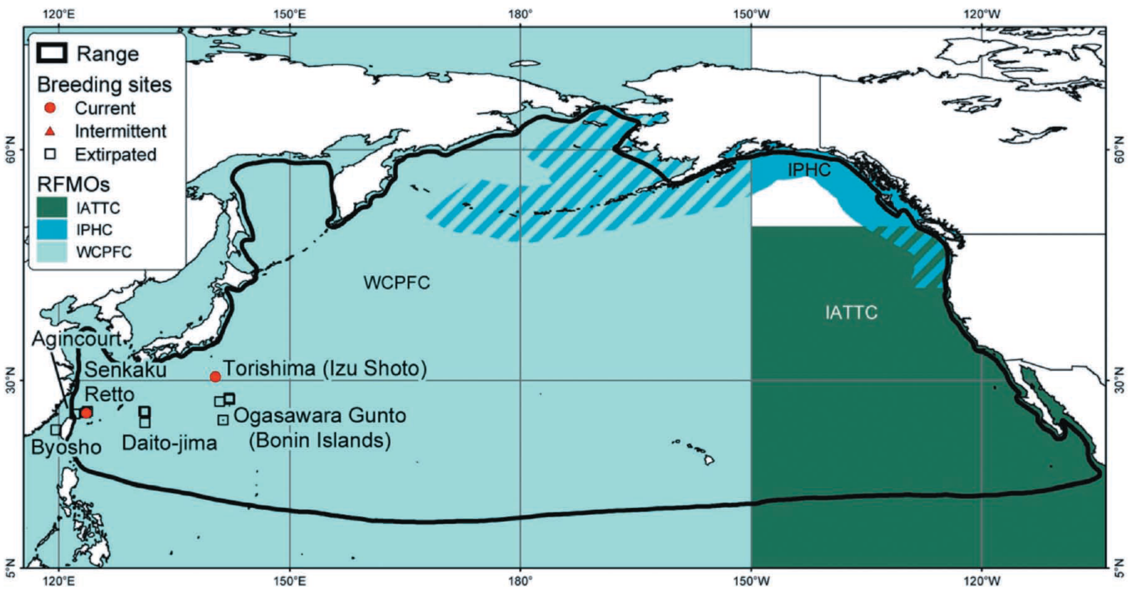


Figure 20: Former and current breeding sites and at-sea range of short-tailed albatross. The species' at-sea range overlaps with three Regional Fishery Management Organizations (RFMOs), but the majority of the time spent at sea is within the Western and Central Pacific Fisheries Commission area. Map by Wieslawa Misiak (from USFWS 2008).

In 2011, the USFWS reported that a short-tailed albatross chick was hatched on Midway Atoll, at the northwestern end of the Hawaiian Archipelago, marking the first confirmed hatching of a short-tailed albatross outside of the islands surrounding Japan in recorded history (USFWS News Release PINWR-11-01; RO-11-03). Prior to that, observations of infertile short-tailed albatross eggs and reports from the 1930s suggested that short-tailed albatross may have nested there in the past. Nesting attempts had been observed, but there had never been more than two short-tailed albatross individuals reported on the Atoll during the same year, and no successful nesting had been confirmed until 2011.

Marine Range

At-sea sightings since the 1940s indicate that short-tailed albatross are distributed widely throughout their historic foraging range in the temperate and subarctic North Pacific Ocean (Sanger 1972). While observations are concentrated along the edge of the continental shelf, in the northern Gulf of Alaska, Aleutian Islands, and Bering Sea (McDermond and Morgan 1993, Sherburne 1993), individual short-tailed albatross have been recorded along the West Coast of North America and as far south as the Baja Peninsula, Mexico (Palmer 1962).

From December through April, short-tailed albatross foraging is primarily concentrated near the breeding colonies, although individual trips may extend hundreds of miles or more from the colony sites. During the non-breeding season, short-tailed albatross range along the Pacific Rim from southern Japan to northern California, primarily along continental shelf margins (Figure **21**). Post-breeding birds either disperse rapidly north to the western Aleutian Islands or stay within the coastal waters of northern Japan and the Kuril Islands throughout the summer, moving in early September into the western Aleutian Islands; once in the Aleutians, most birds travel east toward the Gulf of Alaska (Suryan et al. 2006).

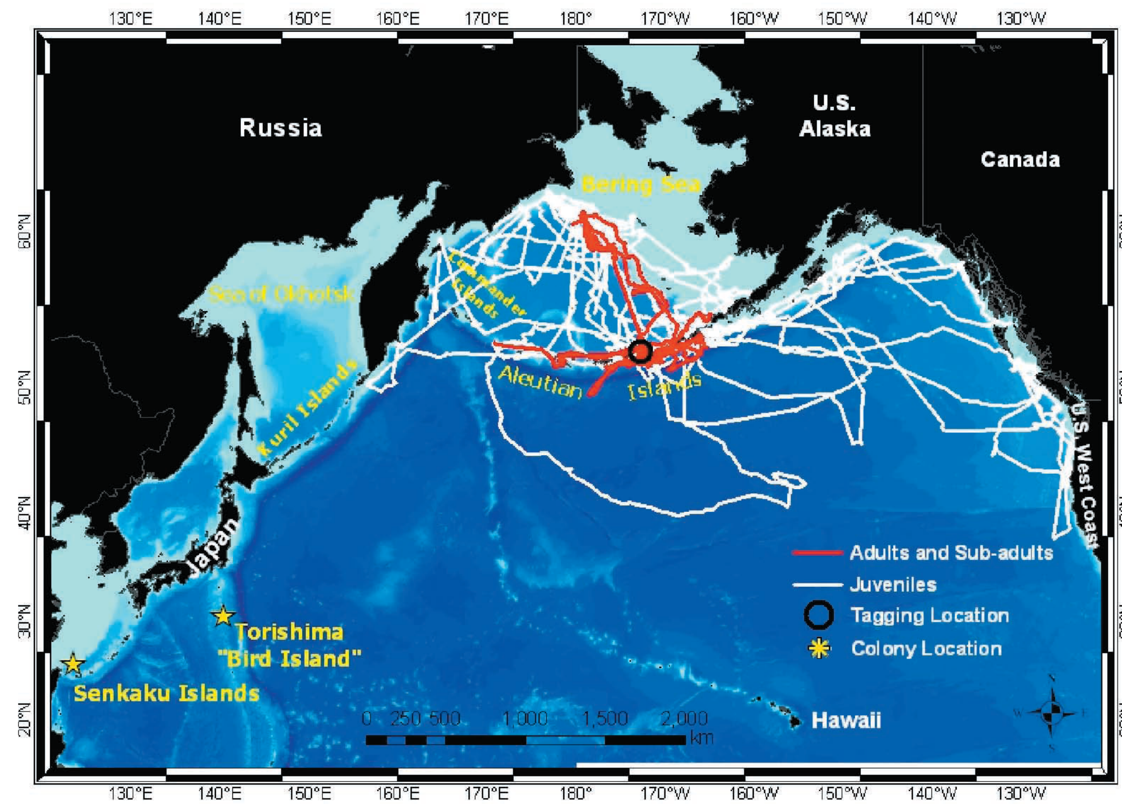


Figure 21: Satellite track lines for adults, sub-adults and juveniles captured at sea near Seguam Pass, Alaska (from USFWS 2008).

Juveniles and sub-adults are prevalent off the west coasts of Canada and the U.S. (Environment Canada 2008). In late September, large flocks of short-tailed albatross have been observed over the Bering Sea canyons (Piatt et al. 2006); these are the only known concentrations of this species away from their breeding islands. Short-tailed albatross forage extensively along continental shelf margins, spending the majority of time within national EEZs, particularly the U.S. (off Alaska), Russia, and Japan, rather than over international waters (Suryan et al. 2007a, Suryan et al. 2007b).

In general, short-tailed albatross show philopatry, returning to their natal colony as breeding adults. However, social attraction techniques (use of decoys and recorded playback of breeding colony sounds) have been used successfully to expand breeding colonies to other parts of Torishima Island; starting in 2008, efforts expanded to another Japanese island, 250 miles to the south of Torishima on Mukojima Island (www.fakr.noaa.gov/protectedresources/seabirds/usfws_stal_translocation_%20factsheet.pdf). Little information is available on the genetic structure of this species, but preliminary analyses of mtDNA sequences suggest extremely high genetic diversity as well as genetic separation of Torishima and Minami-kojima populations (Kuro-o et al. 2010). Additional genetic analyses, especially of newly created breeding populations, are necessary to explore potential bottleneck and founder effects.

Habitat use

At sea, short-tailed albatross individuals spend much of their time feeding in continental shelf-break areas (200–1,000 m depth) east of Honshu, Japan during breeding, and in shelf (0–200 m depth) and shelf-break areas of the Bering Sea, Aleutian chain, and in other Alaskan, Japanese, and Russian waters.

During the brood-rearing period, most foraging bouts are along the eastern coastal waters of Honshu Island, Japan (Suryan et al. 2008). Parents forage primarily off the east coast of Honshu Island, Japan, almost entirely north of Torishima and south of Ishinomaki (Figure **20**) (Suryan et al. 2008), where the warm Kuroshio current from the south collides with the cold Oyashio current from the north. During the non-breeding season, short-tailed albatross range along the Pacific Rim from southern Japan to northern California, primarily along continental shelf margins. During their post-breeding migration, females may have a prolonged exposure to fisheries in Japanese and Russian waters compared to males, which spent more time within the Aleutian Islands and Bering Sea. Juvenile birds have greater exposure to fisheries on the Bering Sea shelf and off the west coasts of Canada and the U.S. (Suryan et al. 2007a).

Short-tailed albatrosses are considered “continental shelf-edge specialists;” they can be relatively common nearshore, but only where upwelling hotspots occur (Piatt et al. 2006). Telemetry studies have also reinforced ship-based observations of individuals in central gyres rather than dispersed widely throughout the subarctic North Pacific and Bering Sea (Suryan et al. 2006, McDermond and Morgan 1993). This association with shelf-break and slope regions may result from the distribution of squids (Suryan et al. 2006).

Because short-tailed albatross forage extensively along continental shelf margins, they spend the majority of their time within EEZs, particularly the U.S. (off Alaska), Russia, and Japan, rather than over international waters (Suryan et al. 2007a, Suryan et al. 2007b). Overall, short-tailed albatross spent the greatest proportion of time off Alaska, and secondarily Russia, during the post-breeding season, regardless of whether the birds were tagged in Japan or Alaska. During the non-breeding season, short-tailed albatross range along the Pacific Rim from southern Japan to northern California, primarily along continental shelf margins.

Critical habitat

Critical habitat has not been designated for this species. In the 2000 final rule, the USFWS determined that designation of Critical Habitat was not prudent, due to the lack of habitat-related threats to the species, the lack of specific areas in U.S. jurisdiction that could be identified as meeting the definition of Critical Habitat, and the lack of recognition or educational benefits accruing to the American people as a result of such designation (65 FR 147:46651-46653).

Status

The short-tailed albatross was originally listed as endangered in 1970, under the Endangered Species Conservation Act of 1969, prior to the passage of today's Endangered Species Act (35 FR 8495). Due to an administrative error, the species was listed as endangered throughout its range except within the United States (50 CFR 17.11). The error was corrected on 31 July 2000, when the U.S. Fish and Wildlife Service published a final rule listing the short-tailed albatross as endangered under the ESA throughout its range, including the United States (65 FR 147:46643-46654). The short-tailed Albatross Recovery Plan was finalized for this species in 2008 (USFWS 2008).

Abundance and trend

As of spring 2011, the global population estimate of short-tailed albatross was 3,463 individuals (P. Sievert and H. Hasegawa, unpubl. data). Pre-exploitation global population estimates of short-tailed albatross are not known, but Dr. Hiroshi Hasegawa estimated there were at least 300,000 breeding pairs on Torishima alone (cited in USFWS 2008). From 1881 to 1903, an estimated five million short-tailed albatross were harvested from the breeding colony on Torishima, and they were harvested into the 1930s (except for a few years following a 1903 volcanic eruption); by 1949, there were no short-tailed albatross breeding at any of the historically-known breeding sites, including Torishima, and the species was thought to be extinct (Austin 1949).

The Torishima Island population growth rate, determined by annual increases in adults observed, eggs laid, and chicks fledged, has been estimated at an annual rate of 6.5–8.0% (H. Hasegawa, unpubl. data, cited in in USFWS 2008).

Threats (from Recovery Plan (USFWS 2008) or listing documents)

Short-tailed albatross face significant threats on breeding colonies and at sea. The major threat of over-exploitation that led to the species' original endangered status no longer occurs. Current threats listed in the Recovery Plan include catastrophic events, such as a volcanic eruption on the main breeding site on Torishima Island. Other catastrophic events, particularly monsoons, can also threaten habitat and nesting success. Past volcanic activity has restricted breeding to sparsely vegetated and steep slopes of loose volcanic soil, and monsoon rains result in frequent mudslides and severe erosion, which can reduce habitat, destroy nests, and reduce breeding success. Global threats may also include indirect adverse effects related to climate change and oceanic regime shifts. While known and potential threats from commercial fishing include U.S. and international demersal longline, pelagic longline, gillnet, jig/troll, and trawl fisheries, short-tailed albatross populations are not declining due to seabird bycatch in commercial fisheries (USFWS 2008). Other threats include contamination from organochlorines, pesticides, metals, and oil, and consumption of plastics. There has been an observed increase in the occurrence of plastics in birds on Torishima Island over the last decade, but the effect on survival and population growth is not known (USFWS 2008).

Fishery impacts

Fisheries have the potential to impact short-tailed albatross populations primarily through bycatch of individuals (USFWS 2008). Albatross, like many seabirds, attack baited hooks of longlines after the hooks are deployed; if they get hooked or snagged, they can be pulled underwater with the rest of the gear and drown (USFWS 2008). Short-tailed albatross may also potentially interact with trawl fisheries. Seabirds, including other albatrosses, fly behind vessels or float in offal plumes that trail beyond vessels, where they can strike the trawl cables (warps) or the sonar cable (third wire) attached to the net (NOAA 2006) or become entangled on the outside of nets towed at or near the surface; those striking cables are very unlikely to show up on the vessels deck to be sampled (USFWS 2008). To date, no short-tailed albatross have been observed to be taken in trawl fisheries, but they have been observed near trawl vessels, and the more abundant black-footed albatross has been observed to be taken in West Coast groundfish trawl fisheries (see further discussion below).

Seabird bycatch in commercial fisheries is a known or potential threat for U.S. and international demersal and pelagic longline fisheries, gillnet fisheries, jig/troll fisheries, and trawl fisheries. Biological opinions issued by the U.S. Fish and Wildlife

Service currently limit incidental take of short-tailed albatross in Alaska fisheries to two birds in two years for the Pacific halibut longline fishery, four birds in two years for the groundfish longline fishery, and two birds over the time period in which the current biological opinion remains in effect for the trawl fishery (USFWS 2003).

Impacts, all fisheries

There have been 16 reported lethal takes of short-tailed albatross in commercial fisheries since 1983; most of these were in hook-and-line fisheries, although some were in net fisheries (Table 20). The most recent reports—two takes in the Alaskan cod longline fishery and one take in the West Coast sablefish longline fishery—were the first reported in U.S. fisheries since 1998.

California, Oregon, Washington One known lethal take of short-tailed albatross has been reported off the West Coast of the continental U.S. In April 2011, a single short-tailed albatross juvenile was reported caught by longline gear in the limited entry sablefish fishery approximately 65 kilometers off the Oregon coast (WCGOP, unpubl. data).

Japan, Russia There is virtually no seabird bycatch information reported from Japanese fisheries, although it is likely that take has occurred in pelagic fisheries in Japan's Exclusive Economic Zone (EEZ); during brood rearing, adults forage for food off the east coast of Honshu, and individuals on Torishima Island have been observed with fishhooks in their mouths of the same type used in Japanese commercial fisheries (USFWS 2008). There is also inadequate seabird bycatch information from Russian fisheries, although demersal longline fisheries in the Russian EEZ are a known threat to short-tailed albatross (USFWS 2008), and short-tailed albatross have been taken in driftnet fisheries that still operate in the Russian EEZ (see Table 20).

Alaska and Hawaii No known takes of short-tailed albatross have been reported in domestic pelagic longline fisheries in the North Pacific. Demersal longline fisheries in the U.S. EEZ off Alaska (Bering Sea/Aleutian Islands area and Gulf of Alaska) are a known threat to short-tailed albatross, with almost all known takes occurring in demersal longline groundfish fisheries; no takes have been reported in groundfish trawl or pot fisheries. Two separate analyses for the demersal groundfish longline fisheries have estimated that, on average, one short-tailed albatross is taken in the Bering Sea hook-and-line fishery each year (Stehn et al. 2001), and mitigation measures have likely reduced this rate since those estimates were developed. U.S.-based pelagic longline swordfish and tuna fisheries in the vicinity of the Hawaiian Islands have the potential to affect short-tailed albatross; overall seabird (and albatross) bycatch rates have declined in Hawaii's pelagic longline fishery since bycatch reduction regulations were promulgated (Gilman and Kobayashi 2005, NMFS 2011). A recent analysis of the continued operation of the Hawaii-based pelagic longline fisheries (NMFS 2011) calculated rates of incidental take of short-tailed albatross of one per year for both the shallow-set longline and deep-set longline fisheries. The rate of incidental takes of seabirds in general and albatross in particular has declined markedly in Alaskan demersal longline fisheries since bycatch reduction regulations were instituted (USFWS 2008).

Table 20: Known short-tailed albatross mortalities associated with North Pacific and West Coast fishing activities since 1983. Data from USFWS (2008), NOAA Fisheries Information Bulletin 10-93 (2010), Yamashina Institute of Ornithology (YIO), and the West Coast Groundfish Observer Program (WCGOP). "In sample" refers to whether a specimen was in a sample of catch analyzed by a fisheries observer. n/a = not applicable

Date	Fishery	Observer program?	In sample?	Bird age	Location	Source
7/15/1983	Net	No	n/a	4 months	Bering Sea	USFWS (2008)
10/1/1987	Halibut	No	n/a	6 months	Gulf of Alaska	USFWS (2008)
8/28/1995	IFQ sablefish	Yes	No	1 year	Aleutian Islands	USFWS (2008)
10/8/1995	IFQ sablefish	Yes	No	3 years	Bering Sea	USFWS (2008)
9/27/1996	Hook-and-line	Yes	Yes	5 years	Bering Sea	USFWS (2008)
1/8/1997	?	n/a	n/a	8 months	Pacific Ocean, Japan	YIO (unpubl. data)
4/23/1998	Russian salmon drift net	n/a	n/a	Hatch-year	Bering Sea, Russia	USFWS (2008)
7/8/1998	Russian salmon drift net	n/a	n/a	3 months	Bering Sea, Russia	YIO (unpubl. data)
9/21/1998	Pacific cod hook-and-line	Yes	Yes	8 years	Bering Sea	USFWS (2008)
9/28/1998	Pacific cod hook-and-line	Yes	Yes	Sub-adult	Bering Sea	USFWS (2008)
7/11/2002	Russian ?	n/a	n/a	3 months	Sea of Okhotsk, Russia	YIO (unpubl. data)
8/29/2003	Russian demersal longline	n/a	n/a	3 years	Bering Sea, Russia	YIO (unpubl. data)
8/31/2006	Russian ?	n/a	n/a	1 year	Kuril Islands, Russia	YIO (unpubl. data)
8/27/2010	Cod freezer longline	Yes	Yes	7-year old	Bering Sea/Aleutian Islands	NOAA Fisheries (2010)
9/14/2010	Cod freezer longline	Yes	Yes	3-year old	Bering Sea/Aleutian Islands	NOAA Fisheries (2010)
4/7/2011	Sablefish demersal longline	Yes	Yes	1-year old	Pacific Ocean/Oregon	WCGOP (unpubl. data)

Impacts, West Coast Groundfish Fisheries

Since 2002, there have been three interactions reported between short-tailed albatross and West Coast groundfish fisheries. From 2002–2009, there were two observed fishery interactions with short-tailed albatross reported by the West Coast Groundfish Observer Program (Figure 22). Both interactions in 2002 were recorded opportunistically as "feeding on catch only" and were not recorded as resulting in mortality (Table 1 in Jannot et al. 2011). In 2011, a single short-tailed albatross was reported caught and killed by longline in the limited entry sablefish fishery approximately 65 kilometers off the Oregon coast (WCGOP, unpubl. data).

Overlap does occur between the West Coast groundfish fisheries and areas and habitat that short-tailed albatross use, so there is potential for impacts from bycatch (Figure **23**). However, there is a paucity of information on short-tailed albatross distribution, which makes risk assessment and impact analysis particularly challenging. When certain endangered species are too rare for quantifying the effects of an activity, a surrogate species may be used (USFWS and NOAA Fisheries Endangered Species Consultation Handbook, p. 4–47). Patterns of North Pacific distribution and habitat use (Fischer et al. 2009) support using black-footed albatross as a proxy for short-tailed albatross. Albatrosses are vulnerable in the North Pacific to longline fishing wherever they co-occur, and takes of both species have occurred in similar habitats and areas to date; the majority of black-footed albatross takes in observed fisheries (limited entry sablefish primary fixed gear and at-sea hake sectors) have also occurred along the shelf-break and north of Cape Mendocino (see Figure 22). Black-footed albatross and short-tailed albatross occupy similar geographic ranges, are similar in size, and exhibit similar feeding behavior, and both have been documented as bycatch in West Coast fisheries (Jannot et al. 2011) and other U.S. fisheries. Black-footed albatross are thus appropriate surrogates to assess the effects of a proposed action and estimate take on endangered short-tailed albatross (USFWS 2004a, NMFS 2011).

Recent analyses by Washington Sea Grant scientists reinforce the use of information on black-footed albatross as a proxy or surrogate for short-tailed albatross (Guy et al. unpubl. data). The authors compiled satellite telemetry data, fisheries-independent surveys, and fisheries-dependent at-sea surveys to examine distribution of short-tailed, black-footed, and Laysan albatross off the West Coast of the U.S. Satellite telemetry data suggested that black-footed and short-tailed albatross spent similar proportions of time among NMFS management areas delineated in PFMC (2008) as well as among depth strata (shelf: <200 m; shelf-break: 200 m–1,000 m; slope-pelagic: >1,000 m). By contrast, a third species, Laysan albatross, spent proportionally more time in slope and less time in shelf-break habitats as well as proportionally greater time in the southernmost NMFS management areas (Guy et al., unpubl. data). Fisheries-independent surveys of black-footed albatross showed similar spatial patterns to the satellite telemetry data as well as considerable spatial overlap (both among depth strata and NMFS management zones) with West Coast groundfish fishery effort, particularly the fixed gear, Pacific hake mid-water trawl, and limited entry bottom trawl fishery sectors (Guy et al., unpubl. data).

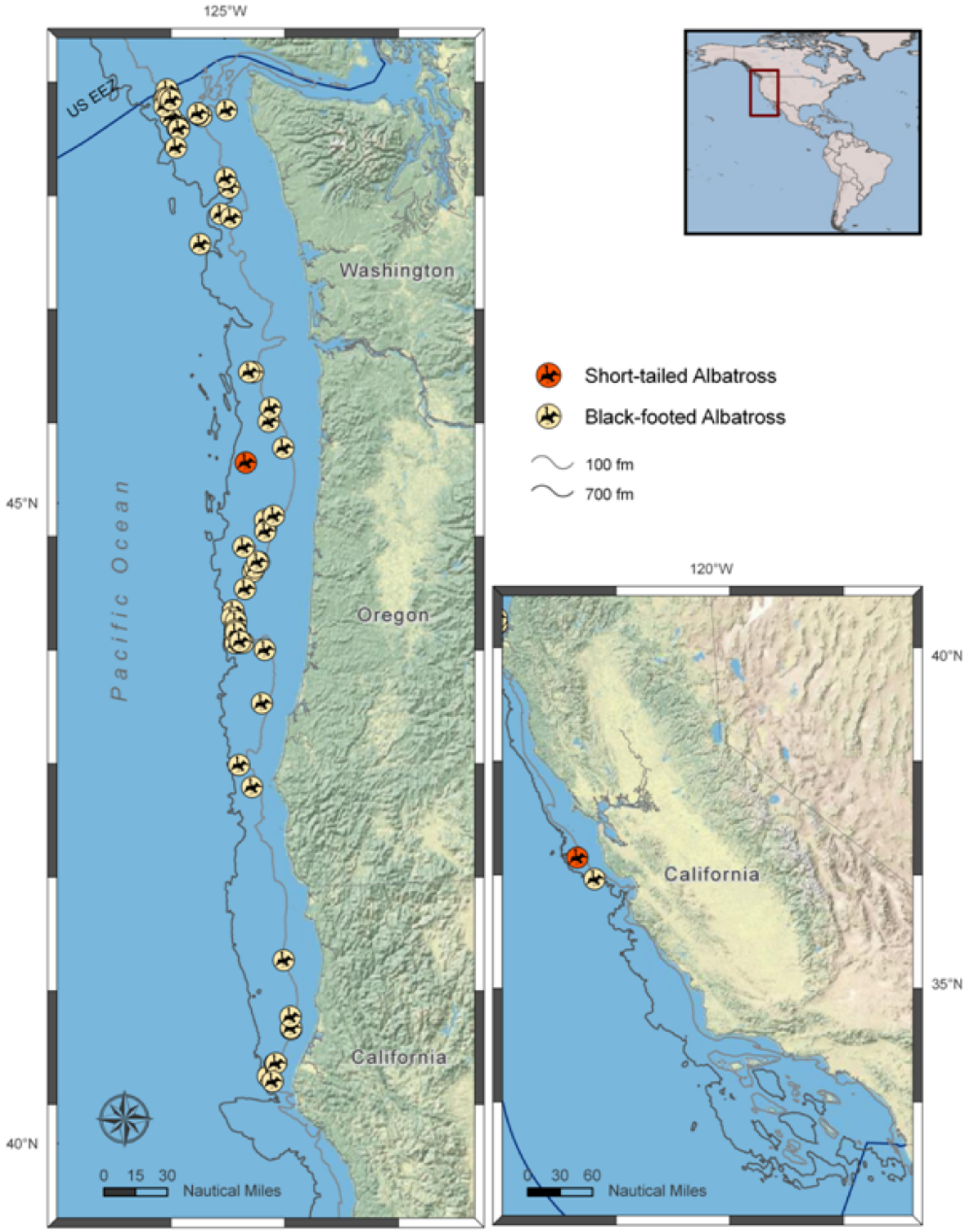


Figure 22: Geographic distribution of black-footed takes and short-tailed albatross interactions by the West Coast Groundfish Observer Program and the At-Sea Hake Observer Program from 2002–2009 (Adapted from Jannot et al. 2011). Takes are either randomly observed (i.e., contribute to bycatch estimates), recorded opportunistically (i.e., non-random, do not contribute to bycatch estimate), or both. Both of the short-tailed albatross interactions were recorded as "feeding on catch only" and did not result in mortality.

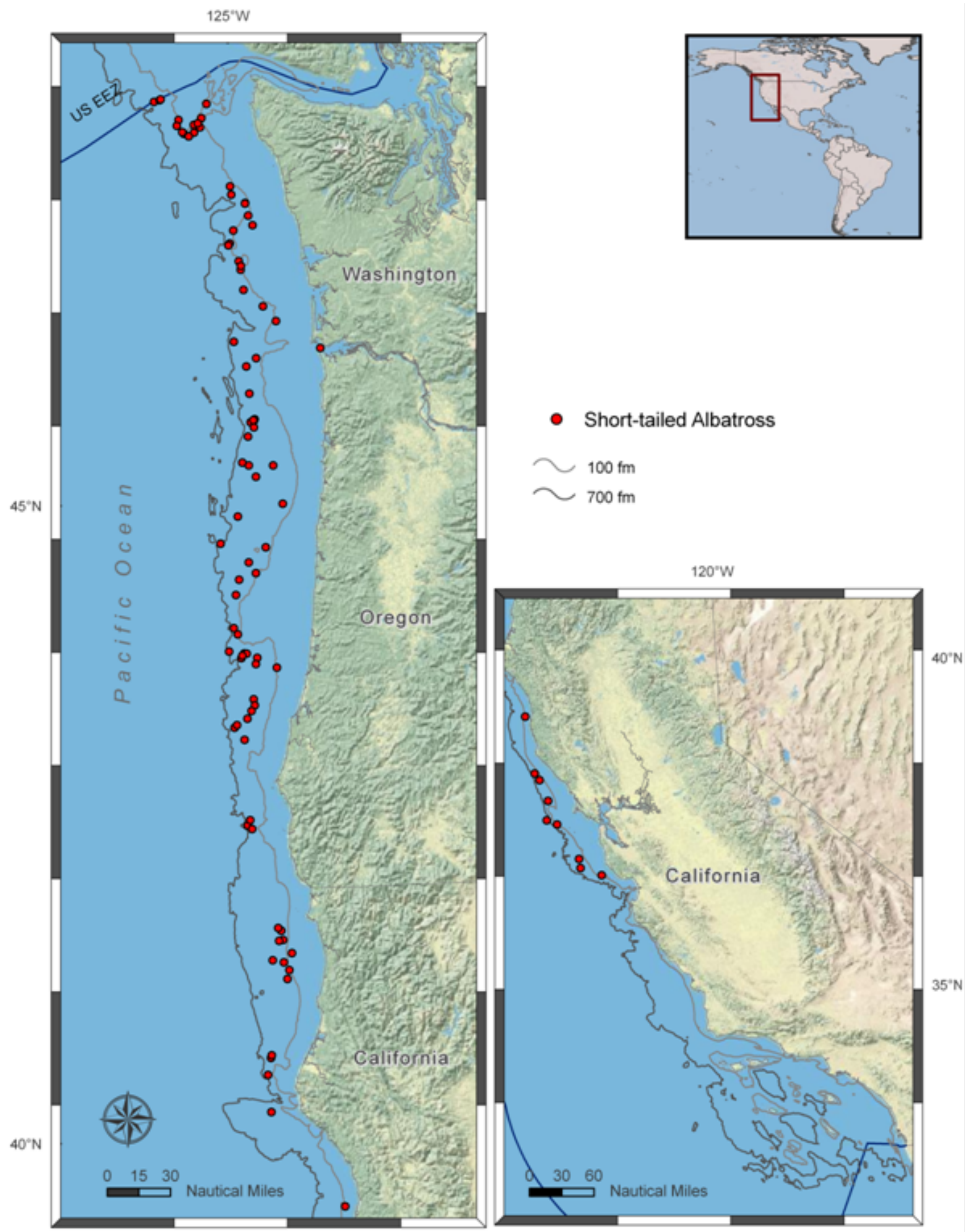


Figure 23: Geographic distribution of opportunistic sightings of short-tailed albatross by the West Coast Groundfish Observer Program from 2001–July 2011.

Opportunistic sightings by fisheries observers of short-tailed albatross also support use of black-footed albatross as a surrogate; data collected by West Coast groundfish fisheries observer programs (Figure 23) show a distribution of sightings largely along the shelf-break that is very similar to the observed takes of black-footed albatross (Figure 22).

Finally, the proportion of opportunistic sightings of short-tailed albatross among NMFS management zones (Figure **24**) and depth strata (Figure **25**) were similar to that found for black-footed and short-tailed albatross satellite telemetry data and fisheries-independent survey data for black-footed albatross (Troy Guy, pers. comm.).

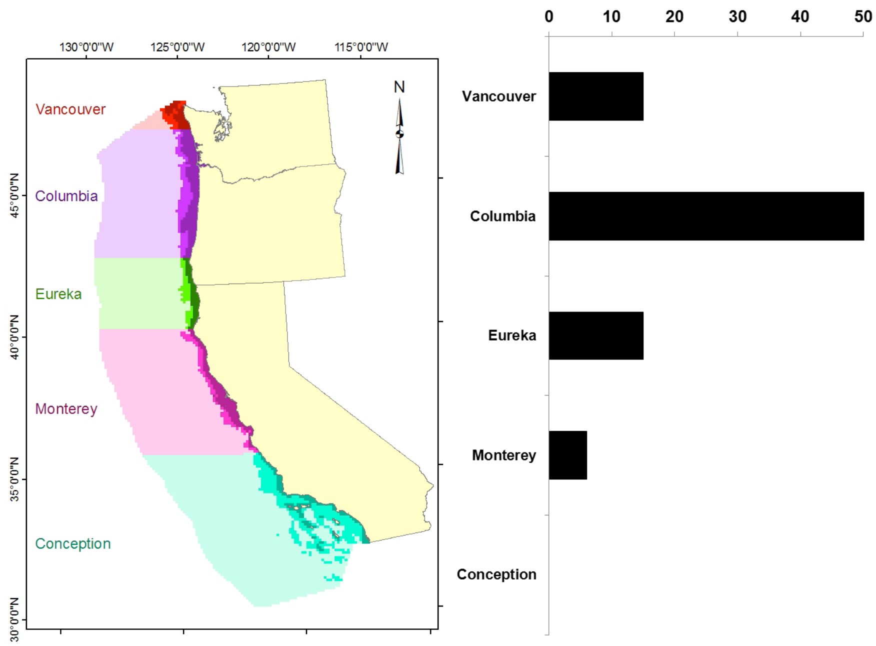


Figure 24: Short-tailed albatross opportunistic sightings in five NMFS management areas. Data from WCGOP fisheries from 2001 to May 2011. Colors delineate management area boundaries; shading delineates bathymetric zones. Figure prepared by Troy Guy, Washington Sea Grant.

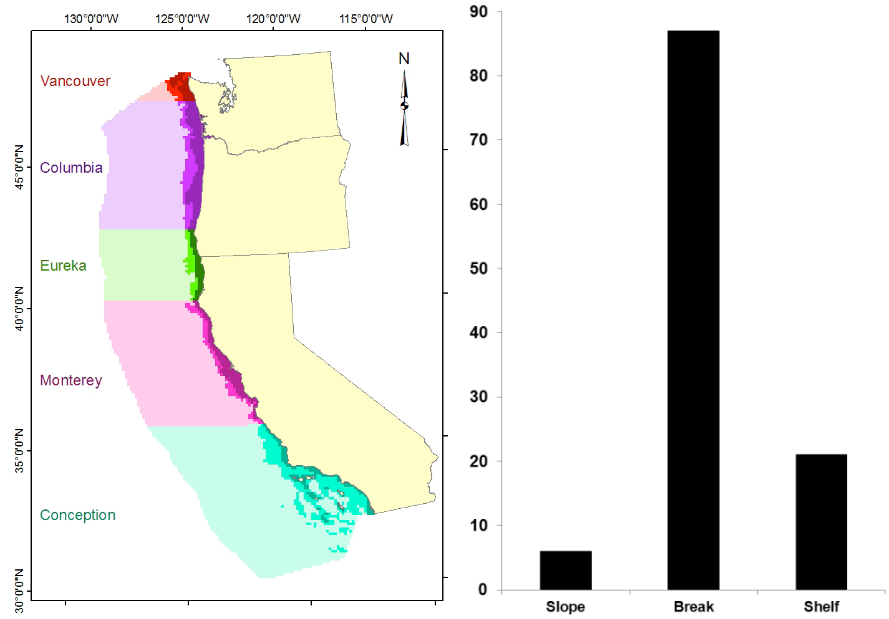


Figure 25: Short-tailed albatross opportunistic sightings in three bathymetric zones. Data from WCGOP fisheries from 2001 to May 2011. Colors delineate management area boundaries; of management areas; shading delineates bathymetric zones. Figure prepared by Troy Guy, Washington Sea Grant.

Short-tailed albatross incidental take estimate based on black-footed albatross mortality rates

West Coast Groundfish Observer Program observers have been deployed aboard vessels since 2001 to document protected species interactions, collect fishery-related information, and perform other biological sampling. The probability of a hooked seabird being observed is a function of observer coverage, the prioritization of the observers' duties onboard the vessels, and the observation skills and reporting accuracy of these individuals (USFWS 2004a, NMFS 2011).

Some groundfish fishery sectors (i.e., non-nearshore fixed gear/limited entry sablefish endorsed) had less than 100% observer coverage from 2002–2009, so observed interactions must be expanded beyond the observer coverage (~9–37% of landings) to estimate fleet-wide interactions (Jannot et al. 2011). This makes estimation of mortality of rare species, such as short-tailed albatross, very difficult because estimates based on a combination of low observer coverage and small numbers of observed takes are typically very uncertain (Jannot et al. 2011). Obtaining a reliable estimate of take when the observed number of takes is 0 or 1 is obviously particularly problematic, and the West Coast Observer Program does not attempt to estimate a fishery-wide take level in such situations.

Because short-tailed albatross take has been too rare for accurately quantifying levels of take in the WCGF, we used black-footed albatross as a surrogate species to estimate the annual mortality rate of short-tailed albatross by the WCGF (see also USFWS 2004a, NMFS 2011). Black-footed albatross are much more common than short-tailed albatross, and annual observed levels of take of this species in WCGF (both fixed gear and trawl) have ranged from 0–48 from 2002–2009, with estimated take from 0–91 (Jannot et al. 2011). Black-footed albatross are similar to short-tailed albatross in size, feeding behaviors, and patterns of distribution documented in surveys and via telemetry studies (see discussion in previous section), making them a reasonable proxy for the much less common short-tailed albatross.

Even with 100% observer coverage, all interactions might not be recorded because animals that become hooked on gear may fall off while the gear is in the water, and thus not be observed (Ward et al. 2004, Gilman et al. 2005). These "drop-offs," along with post-hooking mortality, are often referred to as "unseen mortality." Previous modeling efforts (USFWS 2004a, NMFS 2011) included a correction factor of 31% for drop-offs citing studies of pelagic longline fisheries (Ward et al. 2004, Gilman et al. 2005). Ward et al. (2004) demonstrated that drop-off rates in pelagic longline fisheries may underestimate seabird mortality by as much as 45% on the portions of a set that have soaked the longest. At present, drop-off rates for demersal longline fisheries have not been estimated for West Coast Groundfish Fisheries or for demersal longline fisheries in general (S. Fitzgerald, pers. comm.). In addition, the ratio of observed to unobserved take in trawl fisheries is also unknown, but there is likely to be unobserved take (S. Fitzgerald, pers. Comm.; Ed Melvin pers. Comm.). To take into account uncertainty in this factor, a range of correction factors from 0 to 45%, including the 31% used previously (USFWS 2004a, NMFS 2011), was used here to bracket estimates of short-tailed albatross incidental take.

The short-tailed albatross take (**T**) estimate for the West Coast groundfish fisheries is calculated as follows (following the approach of NMFS 2011):

T = M x **A** x **N**

Where:
M = Fishing mortality of surrogate species (black-footed albatross) = (annual mean estimated number of black-footed albatross in West Coast groundfish fisheries) + (annual mean estimated number of black-footed albatross in West Coast groundfish fisheries * drop-off adjustment) / black-footed albatross global population estimate
A = correction factor to account for differences in distribution between the species
N = Short-tailed albatross population estimate

The annual population level fishing mortality rate in the WCGF (**M**) for black-footed albatross is based on the 8-year (2002–2009) average of the estimated annual mortality of black-footed albatross by the West Coast groundfish fisheries reported in Jannot et al. (2011) (43.75 birds/year), adjusted by a drop-off or removal rate of 31%

(USFWS 2004a, NMFS 2011), and divided by the estimated black-footed albatross population size (245,234 in 2009; Flint 2009).

M = (43.75 + 43.75*0.31)/245,234 = **0.00023/year**.

When previously applied in Hawaiian fisheries, the at-risk area fraction (**A**) was a multiplier that accounted for the fraction of the short-tailed albatross range that overlaps with the fisheries of interest. In the case of the Hawaiian longline fisheries, the black-footed albatross range completely overlapped with the fishery in question, so the at-risk fraction (0.245) was simply derived by dividing the longline fisheries area by the short-tailed albatross range. In our case, black-footed and short-tailed albatross ranges both overlap with the West Coast groundfish fisheries to a similar extent and both species are traveling distances to enter the area; thus, no multiplier is needed to account for differences between the species.

A = **1**

N is the most recent population estimate for short-tailed albatross, which is 3,463 (P. Sievert and H. Hasegawa, unpubl. data).

Therefore,
T = M x **A** x **N**
T = **0.00023 x 1 x 3,463**
T = 0.8

The estimated short-tailed albatross take in the West Coast groundfish fisheries is **0.8** individuals per year.

Sensitivity analyses

This estimate can be influenced by uncertainty in the bycatch estimates of black-footed albatross, the assumed drop-off rate, and the population sizes of the two species. Here, we evaluate the sensitivity of the estimate to the first two sources of uncertainty. Using the lower 90% (21.13/year) and upper 90% (93.5/year) confidence limits for mean annual bycatch estimates of black-footed albatross and a range of drop-off rate scenarios results in a range of values of short-tailed albatross take (T) between 0.30 and 1.91 (Table **21**).

Table 21: Sensitivity analyses of the influence of varying bycatch drop-off rates and black-footed bycatch estimates on estimates of T for short-tailed albatross. Drop-off rates from discussion in NMFS (2011) and mean annual black-footed albatross bycatch rates for 2002–2009 from Jannot et al. (2011) were incorporated into calculations of M for black-footed albatross and then T for short-tailed albatross.

Drop-off rate	**T (short-tailed albatross/year)**		
	Estimate	**Lower 90% BFAL C.L.**	**Upper 90% BFAL C.L.**
0%	0.62	0.30	1.32
27%	0.78	0.38	1.68
31%	0.81	0.39	1.73
45%	0.90	0.43	1.91

Several additional factors could also potentially bias this estimate. With an increasing global short-tailed albatross population (H. Hasegawa, unpubl. data), interactions with fisheries are likely to increase, all else being equal. Opportunistic sightings have been increasing since the observer program began in 2001 (see paragraph below). Exposure to risk could be affected by time spent over the year in the West Coast fisheries areas as opposed to open ocean areas where transiting largely occurs. Exposure could be influenced by temporal overlap of the fisheries and short-tailed albatross presence off the West Coast. Most importantly, the estimates presented here are predicated on black-footed albatross being used as a surrogate for short-tailed albatross. This assumes that the two albatross species have the same mortality rates in the fisheries in question, the same distribution throughout the area (i.e., of the total populations of each species, the same proportion of each species occurs within the West Coast groundfish fisheries area), the same behavior with respect to interacting with vessels (taking bait, etc.), and the same mortality rate once hooked or otherwise impacted.

As additional data are collected or compiled and analyzed (e.g., black-footed albatross bycatch estimates for 2010 and 2011), it may be possible to explore additional methods of estimated short-tailed albatross take. For example, it may be possible to use ratios of STAL/BFAL abundance in the WGCF action area or the take ratio of the two species in other fisheries to obtain another semi-independent estimate of short-tailed albatross take. Higher levels of observer coverage would also be valuable for improving take estimates of this and other rare species.

The level of take estimated using this proxy method, 0.8 per year, is generally consistent with both the observed take (considering the level of observer coverage) and the co-occurrence of short-tailed albatross near the WCGF (Figure 23). Sightings of short-tailed albatross by WCGF observers are relatively common compared to some other fisheries. For example, in Hawaiian longline fisheries, 100% observer coverage has yielded 16 sightings over the last 11 years—one in 2000, two in 2004, three in 2007, three in 2008, three in 2009, and four in 2010 (NMFS unpubl. data); considerably lower observer coverage in the West Coast groundfish fisheries has yielded 95 short-tailed albatross sightings over the last 11 years—four in 2001, 14 in 2002, five in 2003, five in 2004, five in 2005, four in 2006, three in 2007, two in 2008, 16 in 2009, 18 in 2010, and 19 through July 2011 (Figure **23**; WCGOP, unpubl. data).

The short-tailed albatross take estimates presented here are based on black-footed albatross bycatch data collected largely in the absence of seabird bycatch mitigation measures. While some longline vessels in the groundfish fishery use streamer lines and other seabird avoidance gear voluntarily, organized efforts promoting the use of streamer lines have only begun in the last two years. Washington Sea Grant initiated a NMFS-supported streamer line distribution pilot program with tribal fisheries in 2009 and the major longline ports in the Oregon and Washington West Coast Groundfish Observer Program in 2010 (WA Sea Grant 2011). West Coast Groundfish Observer Program observers began documenting the use and characteristics of seabird avoidance gear on fixed gear vessels in 2009, and this information should be available for future analyses of bycatch of short-tailed and black footed albatross in future years (Jannot et al. 2011).

Habitat and trophic effects

West Coast groundfish fisheries target relatively large, commercially valuable fish species, including rockfish, hake, and various mid-water and bottom fish (see Chapter 2 Description of the Fisheries). Short-tailed albatross feed on squid, small fish (including bonitos [Sarda sp.], flying fishes [Exocoetidae] and sardines [Clupeidae]), flying fish eggs, and crustaceans, which are generally not targeted by demersal and trawl fisheries (USFWS 2003)). Indirect trophic effects of the West Coast groundfish fisheries are also expected to be minor and in fact may positively affect the abundance of squid and small fishes through removal of their predators (Appendix A).

Impact of WCGF fisheries on population growth rate

Based on the information summarized above, West Coast groundfish fisheries are imposing some additional (non-natural) mortality on short-tailed albatross. The number of takes per year is very likely to be higher than the number of takes observed (one lethal take over the period of 2002–2011), and based on the black-footed albatross mortality rate, is probably ~1/year and unlikely to be >2/year (Table **21**). On its own, this level of mortality is very small compared to the annual growth rate of the population (~6.5%; currently >200 birds/year). Even when combined with known mortality from other fisheries (Table 20), we see no reason to change the conclusion from the Recovery Plan that mortality from fishing is not a significant impediment to the growth and recovery of the species (USFWS 2008). Analyses of the impacts of Alaskan trawl mortality on the Torishima short-tailed albatross population suggest that trawl-related bycatch exceeding the current expected incidental take in that fishery (two takes in any 5-year period) by even a factor of 10 would have little impact on when the species' proposed recovery goals are achieved (Zador et al. 2008). Our analysis quantifies the level of mortality in another set of fisheries, but does not change the basic conclusion that, at present, the level of estimated fishing mortality is small compared to the annual growth rate of the population. Use of mitigation measures, such as streamer lines or integrated weighted lines like those employed in Alaskan fisheries, would be expected to reduce take even further (USFWS 2008, WA Sea Grant 2011).

*California least tern (*Sterna antillarum browni*)*

General biology[17]

The California least tern is the smallest of the North American terns and is found along the Pacific Coast of California, from San Francisco southward to Baja California. California least terns nest in colonies on relatively open beaches kept free of vegetation by natural scouring from tidal action. The typical colony size is 25 pairs. Most individuals begin breeding in their third year. Their nest is a simple scrape in the sand or shell fragments. A typical clutch is 2 eggs, and both parents incubate and care for the young. They can re-nest up to two times if eggs or chicks are lost early in the breeding season. They are very gregarious and forage, roost, nest, and migrate in colonies. Fall migration commences the last week of July and first week of August. Several weeks before fall migration, adults and young wander along marine coastlines, congregating at prime fishing sites.

Birds breed at 2-3 years, and clutches are usually 2–3 eggs, mostly May–June (July–August nests are likely re-nesting attempts). Incubation usually lasts 20–25 days and is primarily done by the female. Young are tended by both parents, brooded for several days, fly at about 3–4 weeks, and are dependent for a few weeks more. The expected breeding life of an adult (once it has first bred) may be up to 9 years.

The species eats mainly small fishes (generally less than 9 cm long, such as anchovy, topsmelt, surf-perch, killifish, and mosquitofish), obtained by diving from air into shallow water. When breeding, California least terns forage within a few hundred meters of the colony.

Range, migratory behavior, and stock structure

Breeding Range

The California least tern breeding range today is the Pacific Coast of Baja and Alta California, south of the San Francisco Bay Area. Nesting has also occurred sporadically but increasingly at inland sites in the Bay-Delta and Central Valley (USFWS 2009a).

Marine Range

There is scant information, but the non-breeding range is presumed to be the Pacific Coast of North America from central Mexico south to Panama (USFWS 2009a).

[17] Most of the material in this section is from: U.S. Fish and Wildlife Service (USFWS). 2006. California least tern (*Sternula antillarum browni*) 5-Year Review Summary and Evaluation. U.S. Fish and Wildlife Service, Carlsbad, CA. 35 p.

Habitat use

California least terns forage primarily in near shore ocean waters and in shallow estuaries and lagoons. Some adults also feed close to shore in ocean waters. At colonies where feeding activities have been studied, the birds foraged mostly within 3.2 km of the breeding colony and primarily in near shore ocean waters less than 18.3 m deep.

Critical habitat

Critical habitat has not been designated for this species.

Status

The California least tern was originally listed as endangered in 1970 (FR notice: 35 FR 8491). The California least tern Recovery Plan was issued 27 September 1985, which was a revised version of a 1980 revision. A recent status review recommended that the species be down listed to “threatened” status (USFWS 2006).

Abundance and trend

Historically abundant, California least tern numbers had declined to about 600 pairs in the United States at the time of listing. Since then, mostly through active management, the numbers have increased about ten-fold. Breeding numbers of California least terns increased in California from about 600 pairs in the mid-1970s to about 1,200 pairs in 1983, declined by about 25% to around 1,000 pairs from 1984 to 1987 (possibly due to El Nino effects), increased to about 2,800 pairs through about 1994, and increased to approximately 7,100 pairs by 2005 (USFWS 2006).

The California least tern has been concentrated in Los Angeles, Orange, and San Diego counties. The Santa Margarita River mouth in San Diego County generally has supported the largest numbers of terns in recent years. Between Ventura County and the San Francisco Bay area, only Purisma Point and Mussel Rock Dunes (formerly called Guadalupe Dunes), and Vandenberg have been used regularly. Although the annual rate of population change has been variable and sometimes negative, the net result has been a population increase.

Threats (from action plan (USFWS 2009a) or 5-year review (USFWS 2006)

California least tern face significant threats, although these are primarily confined to factors affecting breeding colonies on land. These threats include:

- Destruction of nest sites and curtailment of foraging areas by coastal and marine development
- Modification of nest site habitat by invasive plant species;
- Predation of eggs and chicks; and
- Disturbance at nest sites; reduction in food availability due to climate cycles (e.g., El Nino) and global climate change; flooding of nest sites due to sea level rise; oil spills; increased predators (types and density) due to urbanization.

Major problems include: human use and development of nesting habitat; predation on adults, eggs, and young by birds (e.g., kestrels, night-herons) and mammals (foxes, skunks, and domestic cats and dogs); reduced number of suitable nesting areas, which limits or eliminates tern's anti-predator strategy of shifting among different nesting areas in different years; contaminant levels in eggs; and El Nino conditions may adversely affect population dynamics (NatureServe 2011).

Fishery impacts

Fisheries are unlikely to impact California least tern populations directly through bycatch of individuals. California least terns forage primarily in estuaries, lagoons, and in nearshore environments—inshore of most commercial fisheries. They are also surface feeding birds, preying on a variety of small fishes in shallow waters. When breeding, they forage within a few hundred meters of the colony in waters < 18 m deep. Interactions with fisheries are not mentioned as a threat to the species in the most recent status review (USFWS 2006).

Impacts, all fisheries

There have been no reported lethal takes of California least tern in commercial fisheries.

Impacts, West Coast Groundfish Fisheries

There have been no reported lethal takes of California least tern in West Coast groundfish fisheries. There have been no reports of entangled individuals of this species in California beach monitoring surveys (Moore et al. 2009).

Some overlap does occur between West Coast groundfish fisheries and areas and habitat California least tern use, so there is potential for interaction. However, any potential interactions would be confined to fisheries prosecuted in nearshore areas in southern California and no interactions have been recorded from 2002–2009 in any of the groundfish sectors observed by the West Coast Groundfish Observer Program (Jannot et al. 2011).

Recent compilation of fisheries-independent surveys by Washington Sea Grant scientists (Guy et al., unpubl. data) found that sightings of California least terns were rare and largely confined to the California Bight.

Habitat and trophic effects

West Coast groundfish fisheries target relatively large, commercially valuable fish species, including rockfish, hake, and various mid-water and bottom fish (see Chapter 2 Description of the Fisheries). California least tern feed on mainly small fishes (generally less than 9 cm long, such as anchovy, topsmelt, surf-perch, killifish, and mosquitofish), which are obtained by diving from air into shallow water and are generally not targeted by demersal and trawl fisheries. Indirect trophic effects of the West Coast groundfish fisheries are also expected to be minor and in fact may positively affect the abundance of squid and small fishes through removal of their predators (Appendix A).

Impact of WCGF fisheries on population growth rate

Based on the information summarized above, West Coast groundfish fisheries are not imposing additional (non-natural) mortality on California least tern.

*Marbled murrelet (*Brachyramphus marmoratus*)*

General biology[18]

The marbled murrelet is a small seabird that inhabits the coastal forests and nearshore marine environment along the Pacific Coast of North America from southern California to southern Alaska and the Aleutian Islands.

Marbled murrelets lay a single egg clutch, with incubation and rearing occurring from late March (in California) or late April (Pacific Northwest) through the summer. Fledging ranges from late May (California) or late June (Pacific Northwest) through late summer and early fall (McShane et al. 2004 and references therein).

Marbled murrelets feed on a large variety of small fishes and invertebrates. From McShane et al. (2004):

> In general, small schooling fish and large pelagic crustaceans (euphausiids, mysids, amphipods) represent main prey items for marbled murrelets, with Pacific sand lance (*Ammodytes hexapterus*), northern anchovy (*Engraulis mordax*), immature Pacific herring (*Clupea harengus*), capelin (*Mallotus villosus*), and smelt (Osmeridae) documented as the most common prey species taken.

Foraging occurs primarily in shallow water (< 98 feet), and feeding has been observed at depths from 9.8 to 89 feet (McShane et al. 2004 and references therein).

Range, migratory behavior, and stock structure and habitat use

The marbled murrelet breeding range extends from the Aleutian Islands to central California. Throughout most of its breeding range the marbled murrelet uses old-growth forests for nesting and near shore marine environments for foraging. In the Pacific Northwest and California, murrelets tend forage within 2 km of the coast during the breeding season, with somewhat greater dispersal during the non-breeding season.

Critical habitat

Critical habitat was originally designated for the marbled murrelet in Washington, Oregon, and California on May 24, 1996 (61 FR 26256). Federal and non-federal lands totaling 3,887,800 acres were designated to protect nesting habitats. The U.S. Fish and

---

[18] All of the material in this section is taken directly from: U.S. Fish and Wildlife Service (USFWS). 2009b. Marbled Murrelet (*Brachyramphus marmoratus*) 5-Year Review. U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, Lacey, WA. 108 p. or from McShane et al. (2004).

Wildlife Service proposed to revise critical habitat for the marbled murrelet in June 2008 by removing ~250,000 acres in northern California and Oregon from the 1996 designation, based on new information indicating the areas did not meet the definition of critical habitat. This proposed rule has not been finalized, and critical habitat for the murrelet remains unchanged from the 1996 designation. Critical marine habitat has not been designated.

Status

The Washington, Oregon, and California Distinct Population Segment of the marbled murrelet was originally listed as threatened in 1992 (FR notice: 57 FR 45328). The marbled murrelet Recovery Plan “Recovery Plan for the threatened marbled murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California” was issued on 24 September 1997. A recent 5-year status review in 2009 recommended no changes to the threatened status, noting the listed portion of the species had declined in abundance since the prior (2004) status review and that the recovery criteria for the species had not been met (USFWS 2009b).

Abundance and trend

The total marbled murrelet abundance in North America is estimated to be >900,000, but most of these occur in Alaska (Table 3.2-1 of McShane et al. 2004). The most recent abundance estimate of the listed portion of the species (WA, OR, CA) is 17,700 (95% CI: 14,600–21,000) from northern California to Washington and 174 (91–256) in central California (USFWS 2009b and references therein). The listed portion of the population has been declining since the initiation of monitoring programs in 2000, with a decline of 2.4–4.3% annually in northern CA, OR, and WA, and 15% annually in central CA (USFWS 2009b).

Threats

Original reasons for decline and threats as of the listing included loss of nesting habitat, poor breeding success, predation, gill-net mortality, oil spills and other marine pollution, and possible changes in prey abundance and distribution (USFWS 1997). Changes in threats reported in the 2004 5-year review include: a declining rate of annual habitat loss, particularly on federal lands; improved regulatory mechanisms due to federal and state listings and other state and federal regulation (especially theNorthwest Forest Plan); and new gill-netting regulations in northern California and Washington, which reduced the threat to murrelets (USFWS 2004b). Some threats continued or were assumed to be unchanged, including the lack of development of new habitat to replace historic loss/modification of habitat, predation, and threats from oil spills (USFWS 2004b).

The most recent 5-year review (USFWS 2009b) listed continuing and emerging threats. Terrestrial threats to marbled murrelet populations include the historic and ongoing loss and modification of nesting habitat through commercial timber harvests, human-induced fires, and land conversions, and to a lesser degree, through natural causes, such as wild fires and wind storms. Marine threats to marbled murrelets include changes in the food web and prey quantity and quality,declining prey populations, commercial and recreational fisheries for some prey stocks, some continued (but not quantified) gill-net mortality in northern Washington, high body loads of PCBs in Pacific herring in Puget Sound, HABs, and marine dead zones. Climate change is likely to exacerbate many of these threats result in terrestrial and marine environments.

Fishery impacts

Impacts, all fisheries

Marbled murrelets have been observed to be killed by entanglement in gill-nets, primarily when set in shallow water areas favored by the murrelets (see extensive discussion in McShane et al. [2004]). McShane et al. (2004, and references cited therein) estimated that a minimum of 30 marbled murrelets per year were killed in gill net fisheries in Washington's inland marine waters from 1993–2003, which was estimated to be 0.05–0.11% of the northern Washington population. Gillnet mortality was reported to be substantial in central California prior to 1987, but low to zero after that due to changed fishery regulations (McShane et al. 2004). There are no marine gill net fisheries in Oregon. Some mortality likely continues to occur in inland Washington marine waters and the northern Washington coast, but has not been recently quantified (USFWS 2009b).

Impacts, West Coast Groundfish Fisheries

There has been no reported mortality of marbled murrelets in West Coast groundfish fisheries, and these fisheries are not mentioned or discussed as a threat in the recent status reviews (McShane et al. 2004, USFWS 2009b). The WCGOP reported single interactions with marbled murrelets in 2001 and 2002 in northern California. Both of these occurred in the limited entry trawl sector and were reported as "boarded vessel only" (Table 1 and Figure 1 from Jannot et al. 2011; J. Jannot pers. comm.). However, other alcids were reported as bycatch in WCGF fisheries, including the common murre (*Uria aalge*) and unidentified alcid species (Table 8 of Jannot et al. 2011). Bycatch occurred in the at-sea hake, the CA halibut, limited entry trawl, and nearshore fixed gear sectors. The total level of take was relatively low, however. For example, the estimated common murre take for the WCGF was only 3.4/year from 2002–2009 (with some years not reported), and take of unidentified alcids averaged <1/year (Jannot et al. 2011).

Habitat and trophic effects

West Coast groundfish fisheries target relatively large, commercially valuable fish species, including rockfish, hake, and various mid-water and bottom fish (see Chapter 2

Description of the Fisheries). Marbled murrelet are small, pursuit diving birds, preying mainly on small fishes and euphausiids—species not targeted by demersal fixed gear and trawl fisheries. Indirect trophic effects of the West Coast groundfish fisheries are also expected to be minor and in fact may positively affect the abundance of squid and small fishes through removal of their predators (Appendix A).

Impact of WCGF fisheries on population growth rate

Based on the information summarized above, West Coast groundfish fisheries do not appear to be imposing additional (non-natural) mortality on marbled murrelets. However, some components of the fishery occur in the nearshore areas frequented by murrelets, and a much more common species with similar foraging behavior and diet—the common murre—has been occasionally reported as bycatch in these fisheries. However, the West Coast population of the common murre is approximately 62 times as abundant as the marbled murrelet—population size was estimated at 1.1 million in 1988–89 (Carter et al. 2001)—and likely forages over a broader marine area (Manuwal et al. 2001). The relatively low rate of bycatch of common murres (average of 3.4 per year; Jannot et al. 2011) in WCGF suggests that bycatch of marbled murrelets in these fisheries, although not impossible, is expected to be very rare.

References

Adams, P. B., C. Grimes, J. E. Hightower, S. T. Lindley, M. L. Moser, and M. J. Parsley. 2007. Population status of North American green sturgeon *Acipenser medirostris*. Environmental Biology of Fishes **79**:339-356.

Aguilar, A. 2009. Fin whale. Pages 433-437, *in* W.F. Perrin, B. Wursig, and H.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals, Academic Press, San Diego, CA. 1316 pages.

Allen, B.M, and R. P. Angliss. 2010. Alaska marine mammal stock assessments, 2009. U.S. Department Commerce, NOAA Technical Memorandum NMFS-AFSC-206. 276 pages.

Allen, B.M. and R.P. Angliss. 2010. North Pacific Right Whale (*Eubalaena japonica*): Eastern North Pacific Stock. In: Alaska marine mammal stock assessments, 2009. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-206, pages 195-200.

Allen, B.M, and R. P. Angliss. 2011. Steller sea lion (*Eumetopias jubatus*): Eastern U. S. Stock. In: Alaska marine mammal stock assessments, 2010. U.S. Department Commerce, NOAA Technical Memorandum NMFS-AFSC-223. 292 pages.

Andrews, R. C. 1916. The sei whale (*Balaenoptera borealis* Lesson). Memoirs of the American Museum of Natural History, New Series 1(6):291-388.

Andrews, R.D.1, Straley, J.M., Schorr, G.S.3 Thode, A.M., Calambokidis, J., Lunsford, C.R., O'Connell, V.2011 Satellite tracking Eastern Gulf of Alaska sperm whales: local movements around the shelf-edge contrast with rapid, long-distance migrations across stock boundaries

Arnould, John P. Y. (2009) Southern fur seals (Arctocephalus spp), in Perrin, W. F.; Wursig, Bernd G. and Thewissen, J.G.M. (eds), *Encyclopedia of marine mammals*, pp. 1079-1084, Academic, London, England.

Ashford, J. R., Rubilar, P. S. and Martin, A. R.. 1996. Interactions between cetaceans and longline fishery operations around South Georgia. Marine Mammal Science 12:452-457.

Aurioles-Gamboa, D. and Hernandez-Camacho, C.J. 2006. Notes on the southernmost records of the Guadalupe fur seal, *Arctocephalus townsendi*, in Mexico. Marine Mammal Science, 15: 581-583.

Aurioles-Gamboa, D., Elorriaga-Verplancken, F., and Hernandez-Camacho, C.J. 2010. The current population status of Guadalupe fur seal (*Arctocephalus townsendi*) on the San Benito Islands, Mexico. Marine Mammal Science, 26:402-408.

Austin, O.L. 1949. The Status of Steller's Albatross. Pacific Science 3: 283-295. Environment Canada, 2008. Recovery Strategy for the Short-tailed Albatross (*Phoebastria albatrus*) and the Pink-footed Shearwater (*Puffinus creatopus*) in Canada [Final]. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. vii + 44 pp.

Baker CS, Medrano-Gonzalez L, Calambokidis J, Perry A, Pichler F, Rosenbaum H, Straley JM, Urban-Ramirez J, Yamaguchi M, Von Ziegesar O, 1998. Population structure of nuclear and mitochondrial DNA variation among humpback whales in the North Pacific. Molecular Ecology 7:695-707.

Baker, C. S., T. R. Loughlin, V. Burkanov, C. W. Matson, R. G. Trujillo, D. G. Calkins, J. K. Wickliffe, J. W. Bickham. 2005. Variation of mitochondrial control region sequences of Steller sea lions: the three-stock hypothesis. Journal of Mammalogy 6: 1075-1084.

Baker CS, Steel D, 2010. geneSPLASH: genetic differentiation of 'ecostocks' and 'breeding stocks' in North Pacific humpback whales. In: Symposium on the results of SPLASH humpback whale study Final report and recommendations (Calambokidis J, ed). Quebec City, Canda; 58-59.

Barlow, J. 1994. Abundance of large whales in California coastal waters: a comparison Of ship surveys in 1979/80 and in 1991. Rep. Int. Whal. Comm. 44:399–406.

Barlow, J. 1995. The abundance of cetaceans in California waters. Part 1: Ship surveys in summer and fall of 1991. Fishery Bulletin 93(1):1-14.

Barlow, J. 1997. Preliminary estimates of cetacean abundance off California, Oregon, and Washington based on a 1996 ship survey and comparisons of passing and closing modes. Admin. Rept. LJ-97-11. Southwest Fisheries Science Center, National Marine Fisheries Service, P.O. Box 271, La Jolla, CA. 25 pp

Barlow, J. 2003. Preliminary Estimates of the Abundance of Cetaceans along the U.S. West Coast: 1991–2001. Administrative Report LJ-03-03, available from Southwest Fisheries Science Center, 8604 La Jolla Shores Dr., La Jolla CA 92037. 31pp.

Barlow, J. 2010. Cetacean abundance in the California Current estimated from a 2008 ship-based line-transect survey. NOAA-TM-NMFS-SWFSC-456

Barlow, J. and K.A. Forney. 2007. Abundance and population density of cetaceans in the California Current ecosystem. Fishery Bulletin 105:509-526.

Barlow, J. and Taylor, B. L. 2005. Estimates of sperm whale abundance in the northeastern temperate Pacific from a combined acoustic and visual survey. Marine Mammal Science 21(3):429-445.

Barlow J, Calambokidis J, Falcone EA, Baker CS, Burdin A, Clapham P, Ford JKB, Gabriele C, LeDuc R, Mattila D, Quinn TI, Rojas-Bracho L, Straley JM, Taylor B, Urbán R J, Wade P, Weller D, Witteveen B, Yamaguchi M, 2011. Humpback whale abundance in the North Pacific estimated by photographic capture-recapture with bias correction from simulation studies. Marine Mammal Science Early online. Available http://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.2010.00444.x/pdf.

Barlow J, Ferguson M, Becker E, Redfern J, Forney KA, Vilchis I, Fiedler P, Gerrodette T, Ballance L, 2009. Predictive modeling of cetacean densities in the eastern Pacific Ocean. NOAA Technical Memorandum NMFS-SWFSC-TM-444:206 pp.

Barlow J, Swartz SL, Eagle T, Wade P, 1995. U.S. Marine Mammal Stock Assessments: Guidelines for Preparation, Background, and a Summary of the 1995 Assessments. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-6, 73 p.

Barraclough, W. E. 1964. Contribution to the marine life history of the eulachon *Thaleichthys pacificus*. Bull. Fish. Res. Board Can. 21:1333–1337.

Beamesderfer, R. C. P., M. L. Simpson, and G. J. Kopp. 2007. Use of life history information in a population model for Sacramento green sturgeon. Environmental Biology of Fishes 79:315-337.
Bellinger , M.R.; Banks, M.; Weitkamp, L., and Lawson, P. 2009. Preliminary Report of Mixed Stock Analysis of Chinook Salmon in Pacific Whiting (Hake) Bycatch Collected Shoreside in Newport, Oregon. Project CROOS, http://www.pacificfishtrax.org/media/Chinook_bycatch_in_whiting.pdf
Bellman, M. A., S. A. Heppell, and C. Goldfinger. 2005. Evaluation of US west coast groundfish habitat conservation regulation via analysis of spatial and temporal patterns of trawl fishing effort. Canadian Journal of Fisheries and Aquatic Science 62:2886-2900.
Bellman, M., E. Heery, and J. Hastie. 2008. Estimated discard and total catch of selected groundfish species in the 2007 U. S. West Coast fisheries. Pacific States Marine Fisheries Commission and Northwest Fisheries Science Center, Fishery Resource Analysis and Monitoring Division, Seattle, WA. 77 p. Online at http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/TotalMortality_update2007.pdf [accessed June 2011].
Bellman, M.A. and J. Hastie. 2008. Observed and Estimated Total Bycatch of Salmon in the 2005-2006 West Coast Limited-Entry Bottom Trawl Groundfish Fishery. NWFSC, 2725 Montlake Blvd E., Seattle, WA 98112.
Bellman, M.A., Heery, E., and J. Majewski. 2009. Estimated discard and total catch of selected groundfish species in the 2008 U.S. West Coast fisheries. West Coast Groundfish Observer Program. NWFSC, 2725 Montlake Blvd E., Seattle, WA 98112. Online at: http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/total_mortality_2008_0310-revision.pdf [accessed June 2011].
Bellman, M.A., E. Heery, J. Jannot, and J. Majewski. 2010. Estimated discard and total catch of selected groundfish species in the 2009 U.S. west coast fisheries. West Coast Groundfish Observer Program. National Marine Fisheries Service, NWFSC, 2725 Montlake Blvd E., Seattle, WA 98112. Online at: http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/total_mortality_2009.pdf [accessed June 2011].
Bellman, M.A., E. Heery, and J. Majewski. 2010. Observed and estimated total bycatch of salmon in the 2008 U.S. west coast groundfish fisheries. West Coast Groundfish Observer Program. NWFSC, 2725 Montlake Blvd E., Seattle, WA 98112.
Bellman, M.A., J. Jannot, and J. Majewski. 2011. Observed and estimated total bycatch of salmon in the 2009 U.S. west coast groundfish fisheries. West Coast Groundfish Observer Program. NWFSC, 2725 Montlake Blvd E., Seattle, WA 98112.
Bellman, M.A., J. Jannot, and J. Majewski. 2011. Observed and estimated total bycatch of green sturgeon and eulachon in the 2002-2009 U.S. West Coast fisheries. West Coast Groundfish Observer Program. National Marine Fisheries Service, NWFSC, 2725 Montlake Blvd E., Seattle, WA 98112. Online at: http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/green_sturgeon_eulachon_tm0209rpt_final.pdf [accessed May 2011].

Benson SR, 2002. Ecosystem Studies of Marine Mammals and Seabirds in Monterey Bay, CA, 1996-1999. M.S. Thesis. : San Jose State University.

Benson SR, Croll DA, Marinovic B, Chavez FP, Harvey JT, 2002. Changes in the cetacean assemblage of a coastal upwelling ecosystem during El Niño 1997-98 and the La Niña 1999. Progress in Oceanography 54:279-291.

Benson, S.R., Forney, K.A., Harvey, J.T., Carretta, J.V., and Dutton, P.H. 2007. Abundance, distribution, and habitat of leatherback turtles (Dermochelys coriacea) off California 1990-2003. Fisheries Bulletin 105(3):337-347.

Benson, S.R., Eguchi, T., Foley, D.G., Forney, K.A., Bailey, H., Hitipeuw, C., Betuel P. Samber, B.P., Ricardo F. Tapilatu, R.F. Rei, V., Ramohia, P., Pita, J., and Dutton, P.H. 2011. Large-scale movements and high-use areas of western Pacific leatherback turtles, Dermochelys coriacea." Ecosphere, Vol. 2 No. 7.

Berman-Kowalewski, M., F.M.D. Gulland, S. Wilkin, J. Calambokidis, B. Mate, J. Cordaro, D. Rotstein, J. St. Leger, P. Collins, K. Fahy, and S. Dover. 2010 Association between blue whale (*Balaenoptera musculus*) mortality and ship strikes along the California coast. Aquatic Mammals 36(1): 59-66.

Berzin, A. A. and A. A. Rovnin. 1966. The distribution and migrations of whales in the northeastern part of the Pacific, Chukchee and Bering seas. Izvestiya, Vladivostok. TINRO TOM 58:179–208.

Berzin, A.A. 1972. The sperm whale. Pacific Scientific Research Institute of Fisheries and Oceanography, Moscow. (Translation from Russian 1971 version by Israel Program for Scientific Translations, Jerusalem).

Best, P. B. 1993. Increase rates in severely depleted stocks of baleen whales. ICES J. Mar. Sci. 50:169-186.

Best, P.B. 1994. Seasonality of reproduction and the length of gestation in southern right whales, *Eubalaena australis*. Journal of Zoology 232:175-189.

Best, PB, and Kishino, H. 1998. Estimating natural mortality rate in reproductively active female southern right whales, *Eubalaena australis*. Marine Mammal Science. 14:738-749.

Betz, W., and M. Welch. 1992. Once thriving colony of leatherback sea turtles declining at Irian Jaya, Indonesia. Mar. Turtle Newsl. 56:8-9.

Bhaskar, S. 1985. Mass nesting by leatherbacks in Irian Jaya. WWF Monthly Report, January 1985:15-16.

Bickham, J. W., J. C. Patton, and T. R. Loughlin. 1996. High variability for control region sequences in a marine mammal: implications for conservation and biogeography of Steller sea lions (*Eumetopias jubatus*). Journal of Mammalogy 77: 95-108.

Biggs, D. C., Leben, R. R. and Ortega-Ortiz, J. G. 2000. Ship and satellite studies of mesoscale circulation and sperm whale habitats in the northeast Gulf of Mexico during GulfCet II. Gulf of Mexico Science 18:15-22.

Bleakney, J. S. 1965. Reports of marine turtles from New England and eastern Canada. Can. Field Nat. 79:120-128.

Bonner, W. N. 1986. Marine mammals of the Falkland Islands. British Antarctic Survey, Cambridge, UK.

Bost, C. A., and coauthors. 2009. The importance of oceanographic fronts to marine birds and mammals of the southern oceans. Journal of Marine Systems 78(3):363-376.

Broadhurst, M. K. 2000. Modifications to reduce bycatch in prawn trawls: A review and framework for development. Revs. Fish Biol. Fish. 10:27–60.

Broadhurst, M. K., P. Suuronen, and A. Hulme. 2006. Estimating collateral mortality from towed fishing gear. Fish Fish. 7:180–218.

Brown, R. F., S. D. Riemer, and B. E. Wright. 2002. Population status and food habits of Steller sea lions in Oregon. Rep. from Oregon Dept. of Fish and Wildlife to Oregon State Univ. Contract F0225A-01. 17 pp.

Brownell, R.L. Jr., P.J. Clapham, T. Miyashita and T. Kasuya. 2001. Conservation status of north Pacific right whales. J. Cetacean Res. Manage. (Special issue) 2:269-286.

Builder Ramsey, T., T. A. Turk, E. L. Fruh, J. R. Wallace, B. H. Horness, A. J. Cook, K. L. Bosley, D. J. Kamikawa, L. C. Hufnagle Jr., and K. Piner. 2002. The 1999 Northwest Fisheries Science Center Pacific West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-55. Online at http://www.nwfsc.noaa.gov/assets/25/4277_06162004_130254_tm55.pdf [accessed May 2011].

Burkanov, V. 2009. Russian Steller Sea Lion Research Update. AFSC Quarterly Research Reports, Jan-Feb-Mar 2009. pp 6-11.

Bustard, H.R. 1972. Australian Sea Turtles: Their Natural History and Conservation. Collins, London. 220 pp.

Calambokidis J, Steiger G, Ellifrit D, Troutman B, Bowlby C, 2004. Distribution and abundance of humpback whales and other marine mammals off the northern Washington coast. Fisheries Bulletin 102:563-580.

Calambokidis, J., A. Douglas, E. Falcone, and L. Schlender. 2007. Abundance of blue whales off the US West Coast using photo identification. Contract Report AB133F06SE3906 to Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037. 13p.

Calambokidis J, Falcone EA, Quinn T, Burdin A, Clapham P, Ford JKB, Gabriele C, LeDuc R, Matillia D, Rojas-Bracho L, Straley JM, Taylor B, Urban-Ramirez J, Weller D, Witteveen B, Yamaguchi M, Bendlin A, Camacho D, Flynn KR, Havron A, Huggins J, Maloney N, 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. Olympia, Washington: Cascadia Research.

Calambokidis, J., G.S. Schorr, G.H. Steiger, J. Francis, M. Bakhtiari, G. Marshall, E. Oleson, D. Gendron and K. Robertson. 2008. Insights into the underwater diving, feeding, and calling behavior of blue whales from a suction-cup attached video-imaging tag (CRITTERCAM). *Marine Technology Society Journal* 41(4):19-29.

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 identification. Marine Mammal Science 25 (4): 816-832.

Calkins, D. G., and E. Goodwin. 1988. Investigation of the declining sea lion population in the Gulf of Alaska. Unpubl. Rep., Alaska Dep. Fish and Game, 333 Raspberry Road, Anchorage, AK 99518. 76 pp.

Calkins, D. G., and K. W. Pitcher. 1982. Population assessment, ecology and trophic relationships of Steller sea lions in the Gulf of Alaska. Pages 447-546, in: Environmental assessment of the Alaskan continental shelf. U.S. Dept. Comm. and U.S. Dept. Int., Final Rep. Principal Investigators, 19:1-565.

Carretta, J. V. and K. A. Forney. 1993. Report on 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. U.S. Dep. Commer. NOAA Tech. Memo. NMFS-SWFSC-185. 77 pp.

Carretta, J.V., Lynn, M.S. and Leduc, C.A. 1994. Right whale (*Eubalaena glacialis*) sighting off San-Clemente Island, California. Mar. Mammal Sci. 10:101-5.

Carretta, J. V. and Chivers, S. J. 2004. Preliminary estimates of marine mammal mortality and biological sampling of cetaceans in California gillnet fisheries for 2003. Paper SC/56/SM1 presented to the IWC Scientific Committee, June 2004 (unpublished) [Available from the Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037].

Carretta, J.V., Price, T., Peterson, D., and Read, R. 2004. Estimates of marine mammal, sea turtle, and seabird mortality in the California drift gillnet fishery for swordfish and thresher shark, 1996-2002. Marine Fisheries Review, 66: 21-25.

Carretta, J.V., S.J. Chivers, and K. Danil. 2005. Preliminary estimates of marine mammal bycatch, mortality, and biological sampling of cetaceans in California gillnet fisheries for 2004. Administrative Report LJ-05-10, available from Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037. 17 pp.

Carretta, J. V., Price, T., Petersen, D. and Read, R. 2005b. Estimates of marine mammal, sea turtles, and seabird mortality in the California drift gillnet fishery for swordfish and thresher shark, 1996-2002. Marine Fisheries Review 66(2):21-30.

Carretta, J. V. and Enriquez, L. 2006. Marine mammal bycatch and estimated mortality in California commercial fisheries during 2005. Administrative Report LJ-06-07, available from the Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037. 14p.

Carretta, J.V., Forney, K. A., Muto, M. M., Barlow, J., Baker, J., Hanson, B. and Lowry, M. S. 2006. U.S. Pacific Marine Mammal Stock Assessments: 2005. U.S. Department of Commerce Technical Memorandum, NOAA-TM-NMFS-SWFSC-388, 317 p.

Carretta, J. V. and Enriquez, L. 2007. Marine mammal and sea turtle bycatch in the California/Oregon thresher shark and swordfish drift gillnet fishery in 2006. Administrative Report LJ-07-06, available from the Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037. 9p.

Carretta, J.V., Forney, K. A., Lowry, M. S., Barlow, J., Baker, J., Johnston, D., Hanson, B., Muto, M. M., Lynch, D. and Carswell, L. 2009. U.S. Pacific Marine Mammal Stock Assessments: 2008. U.S. Department of Commerce Technical Memorandum, NOAA-TM-NMFS-SWFSC- 434, 340 p.

Carretta, J.V. and L. Enriquez. 2009a. Marine mammal bycatch in the California/Oregon swordfish and thresher shark drift gillnet fishery in 2008. Administrative Report LJ-09-03. NOAA Fisheries, Southwest Fisheries Science Center, 3333 North Torrey Pines Court, La Jolla, CA 92037. 10p.

Carretta, J.V. and L. Enriquez. 2009b. Marine mammal and seabird bycatch observed in California commercial fisheries in 2007. Administrative Report LJ-09-01. NOAA Fisheries, Southwest Fisheries Science Center, 3333 North Torrey Pines Court, La Jolla, CA 92037. 12p.

Carretta, J. V., K. A. Forney, M. S. Lowry, J. Barlow, J. Baker, D. Johnston, B. Hanson, R.L. Brownell, Jr., J. Robbins, D.K. Mattila, K. Ralls, M. M. Muto, D. Lynch, and L. Carswell. 2010. U.S. Pacific Marine Mammal Stock Assessments: 2009. U.S. Department of Commerce. NOAA Technical Memorandum NMFS-SWFSC-453. 336 pages.

Carretta J, Forney KA, Oleson E, Martien K, Muto M, Lowry M, Barlow J, Baker J, Hanson MB, Lynch D, Carswell L, Brownell RJ, Robbins J, Mattila D, Ralls K, Hill M, 2010. Draft U.S. Pacific marine mammal stock assessments: 2010. NOAA Technical Memorandum NMFS-SWFSC-TM-XXX.

Carretta, J.V. and L. Enriquez. 2010. Marine mammal and sea turtle bycatch in the California/Oregon swordfish and thresher shark drift gillnet fishery in 2009. Administrative Report LJ-10-03. NOAA Fisheries, Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA 92037. 11 p.

Carter, H. R., U. W. Wilson, R. W. Lowe, M. S. Rodway, D. A. Manuwal, J. E. Takekawa, and J. L. Yee. 2001. Population trends of the common murre (*Uria aalge californica*). Pages 33–132 *in* D. A. Manuwal, H. R. Carter, T. S. Zimmerman, and D. L. Orthmeyer, editors. Biology and conservation of the common murre in California, Oregon, Washington, and British Columbia. Volume 1: Natural history and population trends. U.S. Geological Survey, Information and Technology Report USGS/BRD/ITR– 2000-0012, Washington, D.C.

CETAP. 1982. A characterization of marine mammals and turtles in the mid- and north-Atlantic areas of the U.S. Outer Continental Shelf. Cetacean and Turtle Assessment Program, Bureau of Land Management, BLM/YL/TR-82/03, Washington, D.C.

Chen, B.Y., and S.H. Mao. 1981. Hemoglobin fingerprint correspondence and relationships of turtles. Comp. Biochem. Physiol. 68B:497-503.

Chen, B.Y., S.H. Mao, and Y.H. Ling. 1980. Evolutionary relationships of turtles suggested by immunological cross-reactivity of albumins. Comp. Biochem. Physiol. 66B:421-425.

Chua, T.H. 1988. On the road to local extinction: the leatherback turtle (Dermochelys coriacea) in Terengganu, Malaysia. Pages 153-158 in A. Sasekumar, R. D'Cruz, and S. Lim Lee Hong (eds.), Proc. 11th Annual Seminar Malay. Soc. Mar. Sci. Univ. Malaya, Kuala Lumpur.

Clapham, P. J., S. Leatherwood, I. Szczepaniak, and R. L. Brownell. 1997. Catches of humpback and other whales from shore stations at Moss Landing and Trinidad, California, 1919-1926. Marine Mammal Science 13(3):368-394.

Clapham, P., C. Good, S. Quinn, R.R. Reeves, J.E. Scarff and R.L. Brownell, Jr. 2004.

Coleman, B. A. 1986. The 1980 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, length, and age composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-100. Online at: http://www.st.nmfs.noaa.gov/tm/nwc/nwc100.pdf [accessed May 2011].

Coleman, B. A. 1988. The 1986 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, length and age composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-152. Online at: http://www.st.nmfs.noaa.gov/tm/nwc/nwc152.pdf [accessed May 2011].

Colway, C. and D. E. Stevenson. 2007. Confirmed records of two green sturgeon from the Bering Sea and Gulf of Alaska. Northwestern Naturalist **88**:188-192.

Conant, T.A., P.H. Dutton, T. Eguchi, S.P. Epperly, C.C. Fahy, M.H. Godfrey, S.L. MacPherson, E.E. Possardt, B.A. Schroeder, J.A. Seminoff, M.L. Snover, C.M. Upite, and B.E. Witherington. 2009. Loggerhead sea turtle *(Carretta Carretta)* 2009 status review under the U.S. Endangered Species Act. Report of the Loggerhead Biological Review Team to the National Marine Fisheries Service, August 2009. 222 pages.

Cornelius, S.E. 1982. Status of sea turtles along the Pacific coast of Middle America. Pages 211-219 in K.A. Bjorndal (ed.), Biology and Conservation of Sea Turtles. Smithsonian Inst. Press, Washington, D.C. 583 pp.

Cornelius, S.E. 1986. The sea turtles of Santa Rosa National Park. Fundación de Parques Nacionales Costa Rica. 64 pp.

COSEWIC. 2003. COSEWIC assessment and status report on the sei whale *Balaenoptera borealis* (Pacific population, Atlantic population) in Canada. COSEWIC, Committee on the Status of Endangered Wildlife in Canada, Ottawa, Canada.

COSEWIC. 2004. COSEWIC assessment and update status report on the green sturgeon *Acipenser medirostris* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.

Cowlitz Indian Tribe. 2007. Petition to list the Southern Eulachon (*Thaleichthys pacificus*) Distinct Population Segment as threatened or endangered under the federal Endangered Species Act, November 9, 2007. Cowlitz Indian Tribe, Longview, WA.

Dalla Rosa L, 2010. Modeling the foraging habitat of humpback whales. PhD thesis, University of British Columbia, Vancouver. 185 pp.

Davis, R. W., Ortega-Ortiz, J. G., Ribic, C. A., Evans, W. E., Biggs, D. C., Ressler, P. H., Cadyc, R. B., Leben, R. R., Mullin, K. D. and Würsig, B. 2002. Cetacean habitat in the northern oceanic Gulf of Mexico. Deep-Sea Research I 49:121-142.

Department of the Navy (DON). 2008. Request for Letter of Authorization for the incidental harassment of marine mammals resulting from Navy training activities conducted within the northwest traing range complex. September 2008. 323 pp.

Di Natale, A. and Notarbartolo di Sciara, G. 1994. A review of the passive fishing nets and trap fisheries in the Mediterranean Sea and of the cetacean bycatch. Reports of the International Whaling Commission Special Issue 15:189-202.

Dohl, T. P., Guess, R. C., Duman, M. L. and Helm, R. C. 1983. Cetaceans of central and northern California, 1980-83: Status, abundance, and distribution. Report prepared for U. S. Minerals Management Service, contract #14-12-0001-29090. Available from National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115.

Distribution of north Pacific right whales (*Eubalaena japonica)* as shown by 19th and 20th century whaling catch and sighting records. Journal of Cetacean Research and Management 6:1-6.

Donovan, G. P. 1991. A review of IWC stock boundaries. Report of the International Whaling Commission (Special Issue 13).

Douglas, A.B., Calambokidis, J., Raverty, S., Jeffries, S.J., Lambourn, D.M., and S.A. Norman. 2008. Incidence of ship strikes of large whales in Washington State. Journal of the Marine Biological Association of the United Kingdom 88:1121–1132.

Drout V. 2003. Ecology of sperm whales (*Physeter macrocephalus*) in the Mediterranean Sea. PhD Thesis, University of Wales, Bangor.

Dumbauld, B. R., D. L. Holder, and O. P. Langness. 2008. Do sturgeon limit burrowing shrimp populations in Pacific Northwest estuaries. Environmental Biology of Fishes **83**:283-296.

Eckert, S.A. 2002. Distribution of juvenile leatherback sea turtle, *Dermochelys coriacea*, sightings. Marine Ecology Progress Series 230: 289-293.

Eckert, K.L. 1987. Environmental unpredictability and leatherback sea turtle (Dermochelys coriacea) nest loss. Herpetologica 43(3):315-323.

Eckert, K.L. 1993. The biology and population status of marine turtles in the north Pacific Ocean. NOAA Tech. Memo. NMFS. NOAA-TM-NMFS-SWFSC-186. 156 pp.

Eckert, K.L. and S.A. Eckert. 1988. Pre-reproductive movements of leatherback sea turtles (Dermochelys coriacea) nesting in the Caribbean. Copeia 1988:400-406.

Eckert, S.A., K.L. Eckert, P. Ponganis, and G.L. Kooyman. 1989. Diving and foraging behavior of leatherback sea turtles (Dermochelys coriacea). Can. J. Zool. 67:2834-2840.

Eisenberg, J.F. and J. Frazier. 1983. A leatherback turtle (Dermochelys coriacea) feeding in the wild. J. Herpetol. 17:81-82.

Emmett, R. L., S. A. Hinton, S. L. Stone, and M. E. Monaco. 1991. Distribution and abundance of fishes and inveretebrates in west coast estuaries, Volume II: Species life histories summaries. ELMR Rep. 8, NOAA/NOS Stategic Environemental Assessments Division, Rockville, MD.

Emmett, R. L., P. J. Bentley, and G. K. Krutzikowsky. 2001. Ecology of marine predatory and prey fishes off the Columbia River, 1998 and 1999. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-51.

Engelhaupt, D. T. 2004. Phylogeography, Kinship and Molecular Ecology of Sperm Whales (*Physeter macrocephalus*). University of Durham.

Erickson, D. L. and M. A. H. Webb. 2007. Spawning periodicity, spawning migration, and size at maturity of green sturgeon, *Acipenser medirostris*, in the Rogue River, Oregon. Environmental Biology of Fishes **79**:255-268.

Etnier, M.A. 2002. Occurrences of Guadalupe fur seals (*Arctocephalus townsendi*) on the Washington Coast over the past 500 years. Marine Mammal Science, 18:551-557.

Evans, P.G.H. 1997. Ecology of sperm whales (*Physeter macrocephalus*) in the eastern North Atlantic, with special reference to sightings & strandings records from the British Isles. Bulletin de 1'Institut Royal des Sciences Naturelles de Belgique, Biologic 67-Suppl.:37-46.

Falcone, E.A., B. Diehl, A. Douglas, and J. Calambokidis. 2011. Photo-identification of Fin Whales (*Balaeanoptera physalus*) along the US West Coast, Baja California, and Canada. Report to the Southwest Fisheries Science Center, National Marine

Fisheries Service La Jolla, CA, USA.
Felix, F., Haase, B. Davis, J.W., Chiluiza, D. and Amador, P. 1997. A note on recent strandings and bycatches of sperm whales (*Physeter macrocephalus*) and humpback whales (*Megaptera novaeangliae*) in Ecuador. Reports of the International Whaling Commission 47:917-919.
Fischer, K.N., R.M. Suryan, D.D. Roby, and G.R. Balogh. 2009. Post-breeding season distribution of black-footed and Laysan albatrosses satellite-tagged in Alaska: Inter-specific differences in spatial overlap with North Pacific fisheries. Biological Conservation 142: 751-760.
Fiscus, C. H. and G. A. Baines. 1966. Food and feeding behavior of Steller and California Sea Lions. *Journal of Mammalogy* 47: 195-200.
Fleischer, G. W., K. D. Cooke, P. H. Ressler, R. E. Thomas, S. K. de Blois, L. C. Hufnagle, A. R. Kronlund, J. A. Holmes, and C. D. Wilson. 2005. The 2003 integrated acoustic and trawl survey of Pacific hake, *Merluccius productus*, in U.S. and Canadian waters off the Pacific coast. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-65. Online at http://www.nwfsc.noaa.gov/assets/25/6233_06272005_114457_haketm65final.pdf [accessed May 2011].
Fleischer, G. W., K. D. Cooke, P. H. Ressler, R. E. Thomas, S. K. de Blois, and L. C. Hufnagle. 2008. The 2005 integrated acoustic and trawl survey of Pacific hake, *Merluccius productus*, in U.S. and Canadian waters off the Pacific coast. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-94. Online at http://www.nwfsc.noaa.gov/assets/25/6835_11062008_165201_Hake2005SurveyTM94Final.pdf [accessed May 2011].
Fleming A, Jackson J, 2011. Global review of the humpback whale (Megaptera novaeangliae). NOAA-NMFS-SWFSC Tech Memo in press.
Flint, B. 2009. Hawaiian Islands National Wildlife Refuge and Midway Atoll National Wildlife Refuge – Annual Nest Counts through Hatch Year 2009. USFWS, Pacific Remote Islands National Wildlife Refuge Complex, 21 p.
Flinn, R. D., A. W. Trites, E. J. Gregr, and R. I. Perry. 2002. Diets of fin, sei, and sperm whales in British Columbia: An analysis of commercial whaling records, 1963-1967. Marine Mammal Science 18(3):663-679.
Ford, J. K. B., and G. M. Ellis. 2006. Selective foraging by fish-eating killer whales *Orcinus orca* in British Columbia. Marine Ecology-Progress Series 316:185-199.
Ford, J.K.B., G.M. Ellis, P.K. Olesiuk, and K.C. Balcomb. 2009. Linking killer whale survival and prey abundance: food limitation in the oceans' apex predator? Biology Letters, 6: 139-142.
Forney, K. A., J. Barlow, and J. V. Carretta. 1995. The abundance of cetaceans in California waters. Part II: Aerial surveys in winter and spring of 1991 and 1992. Fish. Bull. 93:15–26.
Forney, K.A. 2004. Estimates of cetacean mortality and injury in two U.S. Pacific longline fisheries, 1994-2002. Admin. Rep. LJ-04-07. Southwest Fisheries Science Center, National Marine Fisheries Service, 8604 La Jolla Shores Drive, La Jolla, CA 92037. 17 pp.
Forney, K.A. 2007. Preliminary estimates of cetacean abundance along the U.S. west

coast and within four National Marine Sanctuaries during 2005. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-406. 27p.
Frimodig, A. 2008. Informational report: Bycatch reduction devices used in the pink shrimp trawl fishery. Rep. to California Fish and Game Commission. California Dept. Fish and Game, Marine Region, State Fisheries Evaluation Project. Online at http://www.dfg.ca.gov/marine/pdfs/ brd_report.pdf [accessed 23 February 2010].
Fritts, T.H., M.L. Stinson, and R. Márquez M. 1982. Status of sea turtle nesting in southern Baja California, México. Bull. South. Calif. Acad. Sci. 81(2):51-60.
Fritz, L. and Gelatt, T. 2010. Surveys of Steller Sea Lions in Alaska, June-July 2010. NOAA/NMML Memo. Alaska Fisheries Science Center, 7600 Sand Point Way NE Seattle WA 98115
Gabriel, W. L., and A. V. Tyler. 1980. Preliminary analysis of Pacific coast demersal fish assemblages. Mar. Fish. Rev. 42(3–4):83–88.
Gallo-Reynoso, J. P. 1994. Factors affecting the population status of Guadalupe fur seal, *Arctocephalus townsendi* (Merriam, 1897), at Isla de Guadalupe, Baja California, Mexico. Ph.D. Thesis, University of California, Santa Cruz, 199 p.
Gannier, A. and Praca, E. 2007. SST fronts and the summer sperm whale distribution in the north-west Mediterranean Sea. Journal of the Marine Biological Association of the United Kingdom 87:187-193.
Gendron, D., and S. C. Rosales. 1996. Recent sei whale (Balaenoptera borealis) sightings in the Gulf of California, Mexico. Aquatic Mammals 22(2):127-130.
Gendron, D., S. Lanham, and M. Carwardine. 1999. North Pacific right whale (*Eubalaena glacialis*) sighting South of Baja California. Aquatic Mammals 25:31-34.
Gilman, E., Brothers, N., and Kobayashi, D. 2005. Principles and approaches to abate seabird bycatch in longline fisheries. Fish and Fisheries 6(1): 35-49.
Goff, G.P. and J. Lien. 1988. Atlantic leatherback turtles (*Dermochelys coriacea*) in cold water off Newfoundland and Labrador. Canadian Field Naturalist 102 (1):1-5.
Gordon, J., Moscrop, A., Carlson, C., Ingram, S., Leaper, R., Matthews, J. and Young, K. 1998. Distribution, movements and residency of sperm whales off the Commonwealth of Dominica, eastern Caribbean: implications for the development and regulation of the local whalewatching industry. Reports of the International Whaling Commission 48:551-557.
Gosho, M. E., Rice, D. W. and Breiwick, J. M. 1984. The Sperm Whale, *Physeter macrocephalus*. Marine Fisheries Review 46:54-64.

Green, G. A., J. J. Brueggeman, R.A. Grotefendt, C.E. Bowlby, M. L. Bonnell and K. C. Balcomb. 1992. Cetacean distribution and abundance off Oregon and Washington, 1989-1990. In J. J. Brueggeman, ed. Oregon and Washington marine mammal and seabird surveys. Final report to Minerals Management Services, OCS Study MMS-91-0093, U.S. Department of the Interior by Ebasco Environmental and Ecological Consulting, Inc., 10900 NE 8th Street, Bellevue, WA. 100 pp.
Gregr, E. J., Nichol, L., Ford, J. K. B., Ellis, G. and Trites, A. W. 2000. Migration and population structure of northeastern Pacific whales off coastal British Columbia:

an analysis of commercial whaling records from 1908-1967. Marine Mammal Science 16(4):699-727.
Gregr, E. J., and A. W. Trites. 2001. Predictions of critical habitat for five whale species in the waters of coastal British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 58(7):1265-1285.
Gustafson, R. G., M. J. Ford, D. Teel, and J. S. Drake. 2010. Status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. US Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-105. Online at: http://www.nwfsc.noaa.gov/assets/25/7092_06162010_142619_EulachonTM105WebFinal.pdf [accessed May 2011].
Gustafson, R. G., M. J. Ford, P. B. Adams, J. S. Drake, R. L. Emmett, K. L. Fresh, M. Rowse, E. A. K. Spangler, R. E. Spangler, D. J. Teel, and M. T. Wilson. 2011. Conservation status of eulachon in the California Current. Fish and Fisheries Article first published online: 20 APR 2011 | DOI: 10.1111/j.1467-2979.2011.00418.x.
Haase, B. and Felix, F. 1994. A note on the incidental mortality of sperm whales (*Physeter macrocephalus*) in Ecuador. Reports of the International Whaling Commission Special Issue 15:481-483.
Hamazaki, T. 2002. Spatiotemporal prediction models of cetacean habitats in the mid-western North Atlantic Ocean (from Cape Hatteras, North Carolina, U.S.A. to Nova Scotia, Canada). Marine Mammal Science 18(4):920-939.
Hamilton, P.K., A.R. Knowlton, M.K. Marx and S.D. Kraus. 1998. Age structure and longevity in North Atlantic right whales, *Eubalaena glacialis,* and their relation to reproduction. Mar. Ecol. Prog. Ser. 171:285-292.
Hannah, R. W., and S. A. Jones. 2003. Measuring the height of the fishing line and its effect on shrimp catch and bycatch in an ocean shrimp (*Pandalus jordani*) trawl. Fish. Res. 60:427–438.
Hannah, R. W., and S. A. Jones. 2007. Effectiveness of bycatch reduction devices (BRDs) in the ocean shrimp (*Pandalus jordani*) trawl fishery. Fish. Res. 85:217–225.
Hannah, B., and S. Jones. 2011. 22nd annual pink shrimp review. Oregon Department of Fish & Wildlife, Marine Resources Program, Newport, OR. Online at http://www.dfw.state.or.us/MRP/publications/docs/shrimp_newsletter2011.pdf [accessed June 2011].
Hannah, R. W., S. A. Jones, and V. Hoover. 1996. Evaluation of fish excluder technology to reduce finfish bycatch in the ocean shrimp trawl fishery. ODFW Information Rep. 96-4. Oregon Dept. Fish and Wildlife, Marine Region, Newport.
Hannah, R. W., S. A. Jones, and K. M. Matteson. 2003. Observations of fish and shrimp behavior in ocean shrimp (*Pandalus jordani*) trawls. ODFW Information Rep. 2003-03. Oregon Dept. Fish and Wildlife, Marine Resources Program, Newport
Hannah, R.W., S. A. Jones, M. J. M. Lomeli, and W. W. Wakefield. 2011. Trawl net modifications to reduce the bycatch of eulachon (*Thaleichthys pacificus*) in the ocean shrimp (*Pandalus jordani*) fishery. Fisheries Research doi:10.1016/j.fishres.2011.04.016

Hanni, K.D., Long, D.J., Jones, R.E., Pyle, P., and Morgan, L.E. 1997. Sightings and strandings of Guadalupe fur seals in centeral and northern California, 1988-1995. Journal of Mammalogy, 78: 684-690.

Hanson, M.B., R.W. Baird, J.K.B. Ford, J. Hempelmann-Halos, D.M. Van Doornik, J.R. Candy, C.K. Emmons, G.S. Schorr, B. Gisborne, K.L. Ayres, S.K. Wasser, K.C. Balcomb, K. Balcomb-Bartok, J.G. Sneva, and M.J. Ford. 2010. Species and stock identification of prey consumed by endangered southern resident killer whales in their summer range. Endangered Species Research, 11:69-82.

Harrison, P. 1985. Seabirds, an Identification Guide. Boston: Houghton Mifflin Co., 448 pp.

Hart, J. L. 1973. Pacific fishes of Canada. Bull. Fish. Res. Board Can. 180.

Hasegawa, H. 1984. Status and conservation of seabirds in Japan, with special attention to the Short-tailed Albatross. Pp. 487-500 in Croxall, J.P., P.G.H. Evans and R.W. Schreiber, (eds.). Status and Conservation of the World's Seabirds.

Hasegawa, H. and A. DeGange. 1982. The short-tailed albatross Diomedea albatrus, its status, distribution and natural history. American Birds 6: 806-814.

Hastie, J. 2005. Observed and Estimated Total Bycatch of Salmon in the 2002-2004 West Coast Limited-Entry Trawl Fisheries for Groundfish. NWFSC, 2725 Montlake Blvd E., Seattle, WA 98112.

Hay, D. 2002. The eulachon in Northern British Columbia. *In* T. Pitcher, M. Vasconcellos, S. Heymans, C. Brignall, and N. Haggan (eds.), Information supporting past and present ecosystem models of Northern British Columbia and the Newfoundland Shelf, p. 98–107. Fisheries Centre Research Reports, Vol. 10 No. 1. Univ. British Columbia, Fisheries Centre, Vancouver.

Hay, D. E., and McCarter, P. B. 2000. Status of the eulachon *Thaleichthys pacificus* in Canada. Department of Fisheries and Oceans Canada, Canadian Stock Assessment Secretariat, Research Document 2000-145. Ottawa, Ontario. Online at: http://www.dfo-mpo.gc.ca/csas/csas/DocREC/2000/PDF/2000_145e.pdf [accessed March 2011].

Hay, D.E., P. B. McCarter, R. Joy, M. Thompson, and K. West. 2002. Fraser River eulachon biomass assessments and spawning distribution: 1995-2002. Canadian Science Advisory Secretariat Research Document 2002/117, 57 p.

Heery, E., M.A. Bellman, and J. Hastie. 2009. Observed and estimated total bycatch of salmon in the 2007 U.S. west coast groundfish fisheries. West Coast Groundfish Observer Program. NWFSC, 2725 Montlake Blvd E., Seattle, WA 98112.

Hendrickson, J. R. and Alfred, E. R. 1961. Nesting populations of sea turtles on the east coast of Malaya Bull. Raffles Mus. Singapore. 26: 190-196.

Herman, L. M., C. S. Baker, P. H. Forestall, R. C. Antinoja. 1980. Right whale *Balaena glacialis* sightings near Hawaii: a clue to the wintering grounds? Marine Ecology Progress Series 2:27l-275.

Hill, P. S. and J. Barlow. 1992. Report of a marine mammal survey of the California coast aboard the research vessel McARTHUR July 28-November 5, 1991. U.S. Dep. Commer. NOAA Tech. Memo. NMFS-SWFSC-169. 103 pp.

Hill, P. S., Laake, J. L. and Mitchell, E. 1999. Results of a pilot program to document interactions between sperm whales and longline vessels in Alaska waters. NOAA Technical Memorandum. NMFS-AFSC-108. 42 p.

Hoffman, J. I., C. W. Matson, W. Amos, T. R. Loughlin, and J. W. Bickham. 2006. Deep genetic subdivision within a continuously distributed and highly vagile marine mammal, the Steller's sea lion (*Eumetopias jubatus*). Molecular Ecology 15: 2821-2832.

Horwood, J. 1987. The sei whale: Population biology, ecology and management. (Balaenoptera borealis). Croom Helm, London. 375pp. ISBN 0-7099-4786-0.

Hucke-Gaete, R., Moreno, C. A. and Arata, J. 2004. Operational interactions of sperm whales and killer whales with the Patagonian toothfish industrial fishery off southern Chile. CCAMLR Science 11: 127-140.

Huff, D. D., S. T. Lindley, P. S. Rankin, and E. A. Mora. in review. Green sturgeon physical habitat use in the coastal Pacific Ocean. PLoS One.

Ingólfsson, O. A., A. V. Soldal, I. Huse, and M. Breen. 2007. Escape mortality of cod, saithe, and haddock in a Barents Sea trawl fishery. ICES J. Mar. Sci. 64:1836–1844.

Iniguez, M., and coauthors. 2010. On the occurrence of sei whales, Balaenoptera borealis, in the south-western Atlantic. Marine Biodiversity Records 3: e68.

International Whaling Commission. 1980. Sperm whales: Special Issue. Reports of the International Whaling Commission Special Issue 2:1-275.

International Whaling Commission. (IWC) 1977. Report of the Scientific Committee on sei and Bryde's whales. Rep. Int. Whal. Comm., Spec. Iss. 1:1–9.

International Whaling Commission. (IWC) 1986. Report of the workshop on the status of right whales. Rep. Int. Whal. Comm. (Special issue) 10:1-33.

Israel, A. J., J. F. Cordes, M. A. Blumberg, and B. May. 2004. Geographic patterns of genetic differentiation among collections of green sturgeon. North American Journal of Fisheries Management **24**:922-931.

Israel, J. A., K. J. Bando, E. C. Anderson, and B. May. 2009. Polyploid microsatellite data reveal stock complexity among estuarine North American green sturgeon (*Acipenser medirostris*). Canadian Journal of Fisheries and Aquatic Sciences **66**:1491-1504.

Israel, J. A. and B. May. 2010. Indirect genetic estimates of breeding population size in the polyploid green sturgeon (*Acipenser medirostris*). Molecular Ecology **2010**:1058-1070.

Israel, J. A., M. Neuman, M. L. Moser, S. T. Lindley, B. W. M. Jr., D. L. Erickson, and P. Klimley. in prep. Recent advances in understanding the life history of green sturgeon (*Acipenser medirostris*) and potential anthropogenic threats to this imperiled fish.

Ivashin M. V. and Rovnin, A. A. 1967. Some results of the Soviet whale marking in the waters of the North Pacific. Norsk Hvalfangst-tidende 56:123-135.

James, M.C., C.A. Ottensmeyer and R.A. Myers. 2005. Identification of high-use habitat and threats to leatherback sea turtles in northern waters: new directions for conservation. Ecology Letters 2005(8):195-201.

Jameson, R. J., and K. W. Kenyon. 1977. Prey of sea lions in the Rogue River, Oregon. Journal of Mammalogy 58: 672.

Jannot, J., Heery, E., Bellman, M., Majewski, J. 2011. Estimated bycatch of marine mammals, seabirds, and sea turtles in the US west coast commerical groundfish

fishery, 2002-2009. West Coast Groundfish Observer Program. National Marine Fisheries Service, NWFSC, 2725 Montlake Blvd E., Seattle, WA 98112.
Jaquet, N. 1996. How spatial and temporal scales influence understanding of sperm whale distribution: a review. Mammal Review 26(1):51-65.
Jaquet, N. and Whitehead, H. 1996. Scale-dependent correlation of sperm whale distribution with environmental features and productivity in the South Pacific. Marine Ecology Progress Series 135:1-9.
Jaquet, N., Gendron D., and Coakes, A. 2003. Sperm whales in the Gulf of California: Residency, movements, behavior, and the possible influence of variation in food supply. Marine Mammal Science 19(3):545-562.
JCRMS (Joint Columbia River Management Staff). 2011. 2011 joint staff report concerning stock status and fisheries for sturgeon and smelt. Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife. Online at: http://wdfw.wa.gov/publications/01155/wdfw01155.pdf [accessed June 2011].
Jesse, L.K. 2008. Shoreside Hake Observation Program: 2007 Annual Report. Marine Resources Program, Oregon Department of Fish and Wildlife, Hatfield Marine Science Center. Newport, OR 97365.
Jones, R. E. 1981. Food habits of smaller marine mammals from northern California. Proc. Calif. Acad. Sci. 42:409-433.
Julian, F and Beeson M. 1998. Estimates of marine mammal, turtle, and seabird mortality for two California gillnet fisheries: 1990—1995. Fish. Bull. 96:271-284.
Kaplan I, 2009. Evaluating trophic impacts of California Current groundfish fisheries on protected species. Northwest Fisheries Science Center, Conservation Biology Division, Integrated Marine Ecology Program. 35 pp.
Kaplan, I. Fulton, E.A., Holland, D. Unpublished Manuscript. Linking ecology, economics, and fleet dynamics to evaluate alternative management strategies for US West Coast trawl fisheries.
Kaplan, I. C. and Levin, P. 2009. Ecosystem-based management of what? An emerging approach for balancing conflicting objectives in marine resource management. Fish and Fisheries Series 31:77-95.
Kaplan, I. C. 2011. Evaluating Trophic Impacts of California Current Groundfish Fisheries on Protected Species. Unpublished documnent, NWFSC.
Kasuya T. and Miyashita, T. 1988. Distribution of sperm whale stocks in the North Pacific. Scientific Reports of the Whales Research Institute 39:31-75.
Kawamura, A. 1980. A review of food of balaenopterid whales. Sci. Rep. Whales Res. Inst 32:155-197.
Kawamura, A. 1982. Food habits and prey distributions of three rorqual species in the North Pacific Ocean. Scientific Reports of the Whales Research Institute, Tokyo 34:59-91.

Keller, A. A., T. L. Wick, E. L. Fruh, K. L. Bosley, D. J. Kamikawa, J. R. Wallace, and B. H. Horness. 2005. The 2000 U.S. West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-70. Online at http://www.nwfsc.noaa.gov/assets/25/6459_03102006_131701_Slope2000FinalV2SA.pdf [accessed May 2011].

Keller, A. A., E. L. Fruh, K. L. Bosley, D. J. Kamikawa, J. R. Wallace, B. H. Horness, V. H. Simon, and V. J. Tuttle. 2006a. The 2001 U.S. West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-72. Online at http://www.nwfsc.noaa.gov/assets/25/6460_03202007_121309_ Slope2001TechMemo.pdf [accessed May 2011].

Keller, A. A., B. H. Horness, V. J. Tuttle, J. R. Wallace, V. H. Simon, E. L. Fruh, K. L. Bosley, and D. J. Kamikawa. 2006b. The 2002 U.S. West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-75. Online at http://www.nwfsc.noaa.gov/assets/25/6493_04062006_150352_ Slope2002TM75Final.pdf [accessed May 2011].

Keller, A. A., V. H. Simon, B. H. Horness, J. R. Wallace, V. J. Tuttle, E. L. Fruh, K. L. Bosley, D. J. Kamikawa, and J. C. Buchanan. 2007a. The 2003 U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-86. Online at http://www.nwfsc.noaa.gov/assets/25/6719_01082008_151554_ GroundfishSurvey2003TM86FinalSA.pdf [accessed May 2011].

Keller, A. A., B. H. Horness, V. H. Simon, V. J. Tuttle, J. R. Wallace, E. L. Fruh, K. L. Bosley, D. J. Kamikawa, and J. C. Buchanan. 2007b. The 2004 U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-87. Online at http://www.nwfsc.noaa.gov/assets/25/6656_01152008_153323_ GroundfishSurvey2004TM87FinalSA.pdf [accessed May 2011].

Keller, A. A., B. H. Horness, E. L. Fruh, V. H. Simon, V. J. Tuttle, K. L. Bosley, J. C. Buchanan, D. J. Kamikawa, and J. R. Wallace. 2008. The 2005 U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-93. Online at http://www.nwfsc.noaa.gov/assets/25/6802_08122008_165005_GroundfishSurveyTM93Final.pdf [accessed May 2011].

Kelly, J. T., A. P. Klimley, and C. E. Crocker. 2007. Movements of green sturgeon, *Acipenser medirostris*, in the San Francisco Bay estuary, California. Environmental Biology of Fishes **79**:281-295.

Kenney, R.D. 2002. North Atlantic, North Pacific, and Southern Right Whales. In: Encyclopedia of Marine Mammals. Perrin, W.F., B. Würsig, and J.G.M. Thewissen, eds. Academic Press, pages 806-813.

Kieckhefer T, 1992. Feeding ecology of humpack whales in continental shelf waters near Cordell Bank, California. Master's thesis. Moss Landing, CA: Moss Landing Marine Laboratories.

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. NOAA Technical Memorandum NMFS-NWFSC-62, U.S. Department of Commerce, Seattle, Washington.

Kuro-o, M., Yonekawa, H., Saito, S., Eda, M., Higuchi, H., Koike, H., and Hasegawa, H. 2010. Unexpectedly high genetic diversity of mtDNA control region through severe bottleneck in vulnerable albatross Phoebastria albatrus. Conserv. Genet. 11, 127–137.

Lagerquist B, Mate B, Ortega-Ortiz J, Winsor M, Urbán-Ramirez J, 2008. Migratory movements and surfacing rates of humpback whales (Megaptera novaeangliae) satellite tagged at Socorro Island, Mexico. Marine Mammal Science 24:815-830.

Laist D.W., Knowlton, A.R., Mead, J.G., Collet, A.S. and M. Podesta. 2001. Collisions between ships and whales. Marine Mammal Science 17:35–75.

Lauth, R. R., M. E. Wilkins, and P. A. Raymore Jr. 1997. Results of trawl surveys of groundfish resources of the West Coast upper continental slope from 1989 to 1993. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-79.

Lauth, R. R. 1997a. The 1995 Pacific West Coast upper continental slope trawl survey of groundfish resources off southern Oregon and northern California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-80. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-80.pdf [accessed May 2011].

Lauth, R. R. 1997b. The 1996 Pacific West Coast upper continental slope trawl survey of groundfish resources off Washington and Oregon: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-81. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-81.pdf [accessed May 2011].

Lauth, R. R. 1999. The 1997 Pacific West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon and California: Estimates of distribution, abundance, and composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-98. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-98/Text%20from%20NOAA-TM-AFSC-98.pdf [accessed May 2011].

Lauth , R. R. 2000. The 1999 Pacific West Coast upper continental slope trawl survey of groundfish resources off Washington , Oregon and California: Estimates of distribution , abundance, and length composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-115. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-115/Text%20from%20NOAA-TM-AFSC-115%20.pdf [accessed May 2011].

Lazell, J. 1980. New England waters: critical habitat for marine turtles. Copeia 1980:290-295.

Leatherwood, S., R. R. Reeves, W. F. Perrin, and W. E. Evans. 1982. Whales, dolphins and porpoises of the eastern North Pacific and adjacent Arctic waters: A guide to their identification. NOAA Technical Report NMFS CIRCULAR No. 444. 244p.

LeDuc, R. G., W. L. Perryman, J. W. Gilpatrick, Jr., J. Hyde, C. Stinchcomb, J. V. Carretta, and R. L. Brownell, Jr. 2001. A note on recent surveys for right whales in the southeastern Bering Sea. J. Cetacean Res. Manage. (Special Issue 2):287-289.

Leh, C. 1985. Marine turtles in Sarawak. Mar. Turtle Newsl. 35:1-3.

Lian, C., Singh, R., & Weninger, Q. (December 01, 2009). Fleet restructuring, rent generation, and the design of individual fishing quota programs: Empirical evidence from the Pacific Coast groundfish fishery. Marine Resource Economics, 24, 4, 329-359.

Lien, J. 1994. Entrapments of large cetaceans in passive inshore fishing gear in Newfoundland and Labrador (1979–1990). Rep. Int. Whal. Commn. (Special Issue 15):149–157.

Limpus, C.J. 1982. The status of Australian sea turtle populations. Pages 297-303 in K.A. Bjorndal (ed.), Biology and Conservation of Sea Turtles. Smithsonian Inst. Press, Washington, D.C. 583 pp.

Limpus, C.J. 1995. Global overview of the status of marine turtles: A 1995 viewpoint. Pages 605-609 in K.A. Bjorndal (ed.), Biology and Conservation of Sea Turtles (Revised Edition), Smithsonian Institution Press, Washington, D.C. 615 pp.

Limpus, C.J., and N.C. McLachlan. 1979. Observations on the leatherback turtle, Dermochelys coriacea (L.), in Australia. Aust. Wildl. Res. 6:105-116.

Limpus, C.J., N.C. McLachlan, and J.D. Miller. 1984. Further observations on breeding of Dermochelys coriacea in Australia. Aust. Wildl. Res. 11:567-571.

Lindley, S. T., M. L. Moser, D. L. Erickson, M. Belchik, D. W. Welch, E. L. Rechisky, J. T. Kelly, J. Heublein, and A. P. Klimley. 2008. Marine migration of North American green sturgeon. Transactions of the American Fisheries Society **137**:182-194.

Lindley, S. T., D. L. Erickson, M. L. Moser, G. Williams, O. P. Langness, B. W. McCovey, M. Belchik, D. Vogel, W. Pinnix, J. T. Kelly, J. C. Heublein, and A. P. Klimley. 2011. Electronic tagging of green sturgeon reveals population structure and movement among estuaries. Transactions of the American Fisheries Society **140**:108-122.

Lockyer, C. 1972. The age at sexual maturity of the southern fin whale (Balaenoptera physalus) using annual layer counts in the ear plug. J. Cons. Cons. Int. Explor. Mer 34(2):276–294.

Lockyer, C. 1977. Some estimates of growth in the sei whale, *Balaenoptera borealis*.

Rep. Int. Whal. Comm., Spec. Iss. 1:58–62.
Lockyer, C. H., and A. R. Martin. 1983. The sei whale off Western Iceland. II. Age, growth and reproduction. (Balaenoptera borealis). Report of the International Whaling Commission 33:465-476.-Sc/34/Ba13).
Loughlin, T. R. 1997. Using the phylogeographic method to identify Steller sea lion stocks. Pages 159-171, in: A. E. Dizon, S. J. Chivers, and W. F. Perrin (eds.), Molecular Genetics of Marine Mammals. Society for Marine Mammalogy Spec. Publ. 3.
Mangels, K. F. and T. Gerrodette. Report of cetacean sightings during a marine mammal survey in the eastern Pacific Ocean and the Gulf of California aboard the NOAA ships *McArthur* and *David Starr Jordan* July 28 - November 6, 1993. U.S. Dep. Commer. NOAA Tech. Memo. NMFSSWFSC-221. 88 pp.
Manuwal, D. A., H. R. Carter, T. S. Zimmerman, and D. L. Orthmeyer, Editors. 2001. Biology and conservation of the common murre in California, Oregon, Washington, and British Columbia. Volume 1: Natural history and population trends. U.S. Geological Survey, Biological Resources Division, Information and Technology Report USGS/BRD/ITR– 2000-0012, Washington, D.C. 132 pp.
Marchal, P., Lallemand, P., and Stokes, K. 2009. The relative weight of traditions, economics, and catch plans in New Zealand fleet dynamics. Canadian Journal of Fisheries and Aquatic Sciences, 66: 291–311.
Márquez M., R. 1976. Reservas naturales para la conservacion de las tortugas marinas en México. Inst. Nac. Pesca, México, Ser. Informacion 83:1-21.
Márquez, M., R., and M.A. Carrasco A. 1993. Resúmen de playas de anidación de Tortugas marinas, reservas naturales y actividades de conservación. Programa Nacional de Investigación y Manejo de Tortugas Marinas. INP. CRIP-Manzanillo. Manzanillo, Col. Reporte interno. 21 pp.
Márquez M., R., A. Villanueva, and C. Peñaflores. 1981. Anidación de la Tortuga Laúd Dermochelys coriacea schlegelli en el Pacífico mexicano. Ciencia Pesquera 1(1):45-52 INP, México.
Martin, A.R. 1983. The sei whale off western Iceland. I. Size, distribution and abundance. Rep. Int. Whal. Comm. 33:457–463.
Masaki, Y. 1970. Study on the stock units of sperm whales in the North Pacific. Document SM 70/SP/9 submitted to special IWC sperm whale meeting, Honolulu, March 1970.
Masaki, Y. 1977. The separation of the stock units of sei whales in the North Pacific. (Balaenoptera borealis). Report of the International Whaling Commission Special Issue 1:71-79.
Mate, B. R. 1973. Population kinetics and related ecology of the northern sea lion, *Eumetopias jubatus* and the California sea lion, *Zalophus californi*anus, along the Oregon coast. Ph.D. dissertation, University of Oregon. 94p.
Mate, B. R., B. A. Lagerquist, and J. Calambokidis. 1999. Movements of North Pacific blue whales during their feeding season off southern California and their southern fall migration. Mar. Mamm. Sci. 15(4):1246-1257.
McDermond, D.K., and K.H. Morgan. 1993. Status and conservation of North Pacific albatross. Pages 70-81 in Vermeer, K., Briggs, K.T., Moran, K.H., and D. Seigel-

Causey (eds.), The status, ecology, and conservation of marine birds of the North Pacific. Canadian Wildlife Service Special Publication, Ottawa.
McShane, C., T. Hamer, H. Carter, G. Swartzman, V. Friesen, D. Ainley, R. Tressler, K. Nelson, A. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation report for the 5-year status review of the marbled murrelet in Washington, Oregon, and California. Unpublished report. EDAW, Inc. Seattle, Washington. Prepared for the U.S. Fish and Wildlife Service, Region 1. Portland, Oregon.
Mead, J. G. 1977a. Records of sei and Bryde's whales from the Atlantic coast of the United States, the Gulf of Mexico, and the Caribbean. Reports of the International Whaling Commission 1:113-116.
Mead, J. G. 1977b. Records of sei and Bryde's whales from the Atlantic coast of the United States, the Gulf of Mexico, and the Caribbean. (Balaenoptera borealis, Balaenoptera edeni). Report of the International Whaling Commission Special Issue 1:113-116.-Sc/Sp74/Doc36).
Mellinger, D. K., Stafford, K. M., and Fox, C. G. 2004. Seasonal occurrence of sperm whales (*Physeter macrocephalus*) sounds in the Gulf of Alaska, 1999-2001. Marine Mammal Science 20:48-62.
Melvin, E.F. 2000. Streamer lines to reduce seabird bycatch in longline fisheries. Washington Sea Grant Program, University of Washington. WS-AS-03.
Mesnick, S. L., Taylor, B. L., Archer, F. I., Martien, K. K., Escorza Trevino, S., Hancock-Hanser, B. L., Moreno Medina, S., Pease, V. L., Robertson, K. M., Straley, J. M., Baird, R. W., Calombokidis, J., Schorr, G. S., Wade, P., Burkanov, V., Lunsford, C., Rendell, L., and Morin, P. A. 2011. Sperm whale population structure in the eastern and central North Pacific inferred by the use of single-nucleotide polymorphisms, microsatellites, and mitochondrial DNA. Molecular Ecology Resources 11:278-298.
Mitchell, E. 1975. Preliminary report on Nova Scotia fishery for sei whales (Balaenoptera borealis). Report of the International Whaling Commission 25:218-225.
Mizroch, S. A., D. W. Rice, and J. M. Breiwick. 1984. The blue whale, *Balaenoptera musculus.* Mar. Fish. Rev. 46(4):15–19.
Mizroch, S.A., D.W. Rice, and J.M. Breiwick. 1984. The fin whale, *Balaenoptera physalus*. Mar. Fish. Rev. 46(4):20–24.
Moody, M. F., and T. Pitcher. 2010. Eulachon (*Thaleichthys pacificus*) past and present. Fisheries Centre Research Reports 18: 1-197. Online at: http://www.fisheries.ubc.ca/publications/reports/report18_2.php [accessed March 2011].
Moore, S. E., K. M. Stafford, M. E. Dahlheim, C. G. Fox, H. W. Braham, J. J. Polovina, and D. E. Bain. 1998. Seasonal variation in reception of fin whale calls at five geographic areas in the North Pacific. Mar. Mamm. Sci. 14(3):617-627.
Moore, E., S. Lyday, J. Roletto, K. Litle, J.K. Parrish, H. Nevins, J. Harvey, J. Mortenon, D. Greig, M. Piazza, A. Hermance, D. Lee, D. Adams, S. Allen, and S. Kell. 2009. Entanglements of marine mammals and seabirds in central California and the north-west coast of the United States 2001–2005. Marine Pollution Bulletin 58: 1045–1051.

Morin, P.A., Archer, F.I., Foote, A.D., Vilstrup, J., Allen, E.E., Wade, P., Durban, J., Parsons, K., Pitman, R., Li, L., Bouffard, P., Nielsen, S.A., Rasmussen, M., Willerslev, E., Gilbert, M.T.P., and Harkins, T., Complete mitochondrial genome phylogeographic analysis of killer whales (Orcinus orca) indicates multiple species. Genome Research, 2010. 20(7): p. 908-916.

Morreale, S.J., E.A. Standora, F.V. Paladino, and J.R. Spotila. 1994. Leatherback migrations along deepwater bathymetric contours. Pages 109-110 in B.A. Schroeder and B.E. Witherington (compilers), Proc. Thirteenth Annual Symposium on Sea Turtle Biology and Conservation. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-341. 341 pp.

Moser, M. L. and S. T. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes **79**:243--253.

Moyle, P. B. 2002. Inland fishes of California. University of California Press, Berkeley, CA.

Nasu, K. 1966. Fishery oceanographic study on the baleen whaling grounds. Scientific Reports of the Whales Research Institute Tokyo 20:157-210.

Nasu, K. 1974. Movements of baleen whales in relation to hydrographic conditions in the northern part of the North Pacific Ocean, Bering Sea. Oceanography of the Bering Sea. D. W. Hood and E. J. Kelley, eds. Int. Mar. Sci., University of Alaska, Fairbanks. pp. 345-361.

NatureServe. 2011. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: August 12, 2011).

Nelson, M., M. Garron, R. L. Merrick, R. M. Pace III, and T. V. N. Cole. 2007. Mortality and serious injury determinations for baleen whale stocks along the United States eastern seaboard and adjacent Canadian Maritimes, 2001-2005. U.S. Department of Commerce, NOAA, Northeast Fisheries Science Center.

Nelson, T. C., P. Doukakis, S. T. Lindley, A. D. Schreier, J. E. Hightower, L. R. Hildebrand, R. E. Whitlock, and M. A. H. Webb. 2010. Modern technologies for an ancient fish: tools to inform management of migratory sturgeon stocks. A report for the Pacific Ocean Shelf Tracking (POST) Project.

Nemoto, T., and A. Kawamura. 1977. Characteristics of food habits and distribution of baleen whales with special reference to the abundance of North Pacific sei and Bryde's whales. Report of the International Whaling Commission (Special Issue 1):80-87.

NMFS (National Marine Fisheries Service). 1985. Threatened Fish and Wildlife; Guadalupe Fur Seal. Federal Register [Docket No. 41264-5160, 16 December 1985] 50(241): 51252-51258.

NMFS, 1991. Final Recovery Plan for the humpback whale (Megaptera novaeangliae). November 1991. U.S. Department of Commerice. National Oceanic and Atmospheric Administration. National Marine Fisheries Service. Office of Protected Resources.; 105 pp. .

National Marine Fisheries Service. 1991. Recovery Plan for the sperm whale (*Physetermacrocephalus*). National Marine Fisheries Service, Silver Spring, MD.

(NMFS) National Marine Fisheries Service. 2005. Recovery Plan for the North Atlantic Right Whale (*Eubalaena glacialis*). National Marine Fisheries Service, Silver Spring, MD.

NMFS, 2005. Revisions to Guidelines for Assessing Marine Mammal Stocks. 24 pp. Available at: http://www.nmfs.noaa.gov/pr/pdfs/sars/gamms2005.pdf.

National Marine Fisheries Service. 2006. Endangered and Threatened Species; Designation of Critical Habitat for the Southern Resident Killer Whale. Federal Register 71(229): 69054-69070.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 2007. Leatherback sea turtle (*Dermochelys coriacea*). 5-Year review: Summary and Evaluation. Available from: http://www.nmfs.noaa.gov/pr/pdfs/species/leatherback_5yearreview.pdf

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 2007b. Green sea turtle (*Chelonia mydas*). 5-Year review: Summary and Evaluation. Available from: http://www.nmfs.noaa.gov/pr/pdfs/species/leatherback_5yearreview.pdf

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 2007c. Olive Ridley sea turtle (*Lepidochelys olivacea*). 5-Year review: Summary and Evaluation. Available from: http://www.nmfs.noaa.gov/pr/pdfs/species/oliveridley_5yearreview.pdf

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 2007d. Loggerhead sea turtle (*Carretta Carretta*). 5-Year review: Summary and Evaluation. Available from: http://www.nmfs.noaa.gov/pr/pdfs/species/loggerhead_5yearreview.pdf

National Marine Fisheries Service, Northwest Regional Office. 2007. 2007 Pacific Whiting Fishery Summary. Report, http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/Whiting-Management/Index.cfm.

(NMFS) National Marine Fisheries Service. 2008. Stock Assessment of SEI WHALE (*Balaenoptera borealis*): Eastern North Pacific Stock

National Marine Fisheries Service. 2008. Recovery Plan for Southern Resident Killer Whales (Orcinus orca). National Marine Fisheries Service, Northwest Region, Seattle, Washington.

National Marine Fisheries Service. 2008. Recovery Plan for the Steller Sea Lion (*Eumetopias jubatus*). Revision. National Marine Fisheries Service, Silver Spring, MD. 325 pages.

National Marine Fisheries Service. 2010. Recovery Plan for the sperm whale (*Physeter macrocephalus*). National Marine Fisheries Service, Silver Spring, MD. 165pp.

NMFS (National Marine Fisheries Service). 2010. Endangered and threatened wildlife and plants: Threatened status for southern distinct population segment of eulachon. Federal Register 75(52), 13012–13024. Online at: http://www.nwr.noaa.gov/Publications/FR-Notices/2010/upload/75FR13012.pdf [accessed May 2011].

(NMFS) National Marine Fisheries Service. 2011. Draft Recovery Plan for the Sei Whale (*Balaenoptera borealis*). Prepared by the Office of Protected Resources National Marine Fisheries Service, Silver Spring, MD.

NMFS. 2011. Biological Assessment Continued Operation of the Hawaii-based Pelagic Longline Fisheries. Sustainable Fisheries Division, Pacific Islands Regional Office, National Marine Fisheries Service, Honolulu, Hawaii. July 12, 2011. 73 p.

NMFS (National Marine Fisheries Service). 2011. Endangered and threatened species, designation of critical habitat for southern distinct population segment of eulachon. Federal Register 76(3), 515–536. Online at: http://edocket.access.gpo.gov/2011/pdf/2010-33314.pdf [accessed May 2011].

National Marine Fisheries Service. 2011. Southern Resident Killer Whales (Orcinus orca) 5-year Status Review: Summary and Evaluation. National Marine Fisheries Service, Northwest Region, Seattle, Washington.

NOAA Fisheries. 2010. Information Bulletin 10-93. Sustainable Fisheries Division, Alaska Fisheries Science Center. 17 September, 2010. (http://alaskafisheries.noaa.gov/index/infobulletins/bulletin.asp?BulletinID=7271).

NOAA. 2002. NOAA Fisheries, Northwest Region, Seattle, WA. 2002 West Coast Groundfish Limited Entry Permit Count (www.nwr.noaa.gov/1sustfish/permits/prmcount.htm)

NOAA. 2006. Summary of seabird bycatch in Alaskan Groundfish Fisheries, 1993 through 2004. Unpublished report. Alaska Fisheries Science Center, Seattle, WA.

(NOAA) National Oceanic and Atmospheric Administration. 2006. Endangered and Threatened Species; Revision of Critical Habitat for the Northern Right Whale in the Pacific Ocean. Federal Register, 6 July 2006, 71(129): 38277-38297.

(NOAA) National Oceanic and Atmospheric Administration. 2008a. Endangered and Threatened Species; Endangered Status for North Pacific and North Atlantic Right Whales. Federal Register, 6 March 2008, 73(45): 12024-12030.

(NOAA) National Oceanic and Atmospheric Administration. 2008b. Endangered and Threatened Species; Designation of Critical Habitat for North Pacific Right Whale. Federal Register, 8 April 2008, 73(68): 19000-19002.

(NOAA NMFS) NOAA National Marine Fisheries Service. 2006. Review of the Status of the Right Whales in the North Atlantic and North Pacific Oceans. 62 pp.

NWFSC (Northwest Fisheries Science Center). 2008. Data report and summary analyses of the California and Oregon pink shrimp fisheries, December 2008. NWFSC, Fishery Resource Analysis and Monitoring Division, West Coast Groundfish Observer Program, Seattle, WA. 38 pp. Online at http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/pink_shrimp_report_final.pdf [accessed May 2011].

NWFSC (Northwest Fisheries Science Center). 2009a. Data report and summary analyses of the California and Oregon pink shrimp trawl fisheries. West Coast Groundfish Observer Program, National Marine Fisheries Service, NWFSC, Seattle, WA, 33 pp. Available at: http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/shrimp_twl_report_2009_final.pdf [accessed May 2011].

NWFSC (Northwest Fisheries Science Center). 2009b. Data report and summary analyses of the U.S. West Coast limited entry groundfish bottom trawl fishery. 70 p. West Coast Groundfish Observer Program. NWFSC, 2725 Montlake Blvd E., Seattle, WA 98112. Available at:

http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/trawl_report_2009_final.pdf [accessed May 2011].

NWFSC (Northwest Fisheries Science Center). 2010a. Data report and summary analyses of the U.S. west coast limited entry groundfish bottom trawl fishery. 67 pp. West Coast Groundfish Observer Program. NWFSC, 2725 Montlake Blvd E., Seattle, WA 98112. Available at: http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/trawl_report_2010.pdf [accessed May 2011].

NWFSC (Northwest Fisheries Science Center). 2010b. Data report and summary analyses of the California and Oregon pink shrimp trawl fisheries. West Coast Groundfish Observer Program. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112. 30 pp. Online at: http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/shrimptwl_report_2010.pdf [accessed May 2011].

Northwest Fisheries Science Center (NWFSC). 2011. West Coast Groundfish Observer Manual April 2011 Catch Shares Training Manual. West Coast Groundfish Observer Program. NWFSC,2725 Montlake Blvd. East, Seattle, Washington, 98112.

ODFW (Oregon Department of Fish and Wildlife). 1999. Marine Recreational Fishing in Oregon (brochure). Marine Resources Program, Newport. Oregon.

Ohsumi, S. 1965. Reproduction of the sperm whale in the north-west Pacific. Scientific Reports of the Whales Research Institute 19:1-35.

Ohsumi, S. and S. Wada. 1974. Status of whale stocks in the North Pacific, 1972. Rept. Int. Whal. Commn. 25:114-126.

Ohsumi S. and Masaki, Y. 1975. Japanese whale marking in the North Pacific, 1963-1972. Bulletin Far Seas Fisheries Research Laboratory 12:171-219.

Ohsumi, S. and Masaki, Y. 1977. Stocks and trends of abundance of the sperm whale in the North Pacific. Reports of the International Whaling Commission. 27:167-175.

Olesiuk, P. F., M. A. Bigg, G. M. Ellis, S. J. Crockford, and R. J. Wigen. 1990. An assessment of the feeding habits of harbour seals (Phoca vitulina) in the Strait of Georgia, British Columbia, based on scat analysis. Can. Tech. Rep. Fish. and Aquat. Sci. No. 1730.

Olesiuk, P. F., M. A. Bigg, and G. M. Ellis. 1990a. Life history and population dynamics of resident killer whales (Orcinus orca) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Commission, Special Issue 12:209-243

Olivarría, C. 2002. Interactions between odontocetes and the artisan fisheries of Patagonian toothfish Disossitchus eleginoides off Chile, Eastern South Pacific. Toothed Whale/Longline Fisheries Interactions in the South Pacific Workshop SREP.

Olsen, E., and coauthors. 2009. First satellite-tracked long-distance movement of a sei whale (Balaenoptera borealis) in the North Atlantic. Aquatic Mammals 35(3):313-318.

Olson, S.L. and P.J. Hearty. 2003. Probable extirpation of a breeding colony of Short-tailed Albatross (Phoebastria albatrus) on Bermuda by Pleistocene sea-level rise. Proc. Nat. Acad. Sci. 100: 12825-12829.

Omura, H. 1958. North Pacific right whale. Sci. Rep. Whales. Res. Inst. (Japan) 13.
Omura H. and Ohsumi, S. 1964. A review of Japanese whale marking in the North Pacific to the end of 1962, with some information on marking in the Antarctic. Norsk Hvalfangst-tidende 53:90-112.
Omura, H., S. Ohsumi, K.N. Nemoto and T. Kasuya. 1969. Black right whales in the north Pacific. Sci. Rep. Whales Res. Inst. (Japan) 21.
Omura, H. 1986. History of right whale catches in the waters around Japan. Rep. Int. Whal. Commn (special issue) 10:35-41.
Palmer, R.S. 1962. Short-tailed albatross (Diomedea albatrus). Handbook of North American Birds 1: 116-119.
Parks, N. B., F. R. Shaw, and R. L Henry. 1993. Results of a 1988 trawl survey of groundfish resources of the upper continental slope off Oregon. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-23. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-23.pdf [accessed May 2011].
Perry, S.L., D.P. DeMaster, and G.K. Silber. 1999. The Great Whales: History and Status of Six Species Listed as Endangered Under the U.S. Endangered Species Act of 1973. A Special Issue of the Marine Fisheries Review. Marine Fisheries Review 61:1-74.
Peterson, R.S., Hubbs, C.L., Gentry, R.L., and Delong, R.L. 1968. The Guadalupe fur seal: Habitat, Behavior, Population Size, and Field Identification. Journal of Mammalogy, 49: 665-675
PFMC (Pacific Fishery Management Council. October 2002. Pacific Fishery Management Council. Draft Environmental Impact Statement for the Proposed Groundfish Acceptable Biological Catch and Optimum Yield Specifications and Management Measures 2003 Pacific Coast Groundfish Fishery.
PFMC. 2005. Final Environmental Impact Statement for Amendment 19 to Conserve and Protect Essential Fish Habitat for West Coast Groundfish.
PFMC. 2008. Status of the Pacific Coast Groundfish Fishery; Stock Assessment and Fishery Evaluation; Volume 1 – Description of the Fishery.
PFMC (Pacific Fishery Management Council). 2008. Status of the Pacific Coast coastal pelagic species fishery and recommended acceptable biological catches. Stock assessment and fishery evaluation—2008. Online at http://www.pcouncil.org/bb/2008/0608/G1a_ATT1_0608.pdf [accessed May 2011].
PFMC. 2008b. Pacific coast groundfish fishery management plan for the California, Oregon, and Washington groundfish fishery as amended through Amendment 19, including Amendment 15. Pacific Fishery Management Council, Portland, OR 97220, July 2008. 167 p.
PFMC. 2011. Proposed Harvest Specifications and Management Measures for the 2011-2012 Pacific Coast Groundfish Fishery and Amendment 16-5 to the Pacific Coast Groundfish Fishery Management Plan to Update Existing Rebuilding Plans and Adopt a Rebuilding Plan for Petrale Sole; Final Environmental Impact Statement.
Piatt, J.F., J. Wetzel, K. Bell, A.R. DeGange, G.R. Balogh, G.S. Drew, T. Geernaert, C. Ladd, and G.V. Byrd. 2006. Predictable hotspots and foraging habitat of the

endangered short-tailed albatross (Phoebastria albatrus) in the North Pacific: implications for conservation. Deep Sea Research II 53: 387-398.
Pike, G. C., and I. B. Macaskie. 1969. Marine mammals of British Columbia. Bulletin of the Fisheries Research Board of Canada 171:1-54.
Pitcher, K. W., P. F. Olesiuk, R. F. Brown, M. S. Lowry, S. J. Jeffries, J. L. Sease, W. L. Perryman, C. E. Stinchcomb, and L. F. Lowry. 2007. Status and trends in abundance and distribution of the eastern Steller sea lion (*Eumetopias jubatus*) population. Fish. Bull. 107: 102-115.
Pitman, R.L. and P. Ensor. 2003. Three forms of killer whales (Orcinus orca) in Antarctic waters. Journal of Cetacean Research and Management 5(2): 131–139.
Pritchard, P.C.H. 1971. The leatherback or leathery turtle, Dermochelys coriacea. IUCN Monograph 1:1-39.
Pritchard, P.C.H. 1973. International migrations of South American sea turtles (Cheloniidae and Dermochelyidae). Anim. Behav. 21:18-27.
Pritchard, P.C.H. 1977. Marine turtles of Micronesia. Chelonia Press, San Francisco. 83 pp.
Pritchard, P.C.H. 1980. Dermochelys coriacea: leatherback turtle. Catalog Amer. Amphib. Rept. 238:1-4.
Pritchard, P.C.H. 1982a. Nesting of the leatherback turtle, Dermochelys coriacea, in Pacific Mexico, with a new estimate of the world population status. Copeia 1982:741-747.
Pritchard, P.C.H. 1982b. Marine turtles of the South Pacific. Pages 253-262 in K.A. Bjorndal (ed.), Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, D. C. 583 pp.
Pritchard, P.C.H. 1982c. Sea turtles of Micronesia. Pages 263-274 in K.A. Bjorndal (ed.),Biology and Conservation of Sea Turtles. Smithsonian Inst. Press, Washington, D. C. 583 pp.51
Pritchard, P.C.H., and P. Trebbau. 1984. The turtles of Venezuela. Society for the Study ofAmphibians and Reptiles, Contrib. Herpetol. 2.
Raum-Suryan, K. L., K. W. Pitcher, D. G. Calkins, J. L. Sease, and T. R. Loughlin. 2002. Dispersal, rookery fidelity and metapopulation structure of Steller sea lions (*Eumetopias jubatus*) in an increasing and a decreasing population in Alaska. Marine Mammal Science 18: 746-764.
Raum-Suryan, K.L., M.J. Rehberg, G.W. Pendleton, K.W. Pitcher, T.S. Gelatt. 2004. Development of dispersal, movement patterns, and haul-out use by pup and juvenile Steller sea lions (*Eumetopias jubatus*) in Alaska. Marine Mammal Science 20: 823-850.
Raum-Suryan, K. L., Jemison, L. A., Pitcher, K. W. 2009. Entanglement of Steller sea lions (*Eumetopias jubatus*) in marine debris: identifying causes and finding solutions. Marine Pollution Bulletin 58: 1487-1495.
Raymore Jr., P. A., and K. L. Weinberg. 1990. 1984 spring and autumn surveys of Pacific West Coast upper continental slope groundfish resources. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-F/NWC-179.
Read, A.J. 1994. Interactions between cetaceans and gillnet and trap fisheries in the northwest Atlantic. Rep. Int. Whal. Commn. (Special Issue 15):133–147.

Reilly, S.B., Bannister, J.L., Best, P.B., Brown, M., Brownell Jr., R.L., Butterworth, D.S., Clapham, P.J., Cooke, J., Donovan, G.P., Urbán, J. & Zerbini, A.N. 2008. *Balaenoptera borealis*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4.

Reeves, R. R., Leatherwood S., Karl, S. A., and Yohe, E. R. 1985. Whaling results at Akutan (1912-39) and Port Hobron (1926–37), Alaska. Reports of the International Whaling Commission. 35:441-457.

Reeves, R. R., P. J. Clapham, R. L. Brownell, and G. K. Silber. 1998. Recovery Plan for blue whale (*Balaenoptera musculus*). Office of Protected Resources, NMFS, NOAA, Silver Springs, Maryland. 30 pp.

Reeves, R. R., B. S. Stewart, P. J. Clapham, and J. A. Powell. 2002. Guide to marine mammals of the world. Chanticleer Press, Inc., New York.

Rice, D. W. & Fiscus, C. H. 1968. Right whales in the southeastern North Pacific. *Norsk Hvalfangst-Tidende.* **57:**105–107.

Rice, D. W. 1974. Whales and whale research in the eastern North Pacific. Pages 170-195 *in* W. E. Schevill, editor. The Whale Problem: A Status Report. Harvard University Press, Cambridge, MA.

Rice, D. W. 1977. Synopsis of biological data on the sei whale and Bryde's whale in the eastern North Pacific. Report of the International Whaling Commission (Special Issue 1):92-97.

Rice, D.W., 1978. The humpback whale in the North Pacific: Distribution, exploitation, and numbers. Pages 29–44 in K. S. Norris and R. R. Reeves, eds. Report on a workshop on problems related to humpback whales (Megaptera novaeangliae) in Hawaii. Contract Report to the U.S. Marine Mammal Commission. NTIS PB-280–794. 90 pp.

Rice, D. W. 1989. Sperm Whale *Physeter macrocephalus*. Pp. 177-233 In S. H. Ridgway and R. Harrison (eds.), Handbook of Marine Mammals. Vol. 4. River Dolphins and the Larger Toothed Whales. Academic Press, New York.

Rice, D. W. 1998. Marine mammals of the world: Systematics and distribution. Special Publication Number 4. The Society for Marine Mammology, Lawrence, KS. 231p.

Riemer, S. D., Wright, B. E., Brown, R. F., 2010. Food habits of Steller sea lions (*Eumetopias jubatus*) off Oregon and northern California, 1986–2007. Fishery Bulletin 109:369-381.

Robbins J, 2010. Entanglement scarring on North Pacific humpback whales. In: Symposium on the results of SPLASH humpback whale study Final report and recommendations (Calambokidis J, ed). Quebec City, Canada; 18-19.

Robbins J, Landry S, Mattila D, 2009. Estimating entanglement mortality from scar-based studies. Scientific Committee Meeting of the International Whaling Commission, 2009. SC/61/BC3.

Robbins J, Mattila D, 2004. Estimating humpback whale (Megaptera novaeangliae) entanglement rates on the basis of scar evidence. Report to the Northeast Fisheries Science Center, National Marine Fisheries Service.

Rosenbaum, H.C, R.L. Brownell Jr., M.W. Brown, C. Schaeff, V. Portway, B.N. White, S. Malik, L.A. Pastene, N.J. Patenaude, C.S. Baker, M. Goto, P.B. Best, P.J. Clapham, P. Hamilton, M. Moore, R. Payne, V. Rowntree, C.T. Tynan, and R.

DeSalle. 2000. Worldwide genetic differentiation of *Eubalaena*: questioning the number of right whale species. Molecular Ecology 9:1793-1802.
Ross, J.P., and M.A. Barwani. 1982. Historical decline of loggerhead, ridley, and leatherback sea turtles. Pages 189-195 in K.A. Bjorndal (ed.), Biology and Conservation of Sea Turtles. Smithsonian Inst. Press, Washington, D. C. 583 pp.
Rowlett, R.A., G.A. Green, C.E. Bowlby, and M.A. Smultea. 1994. The first photographic documentation of a northern right whale off Washington State. Northwestern Naturalist 75:102-104.
Rowntree, V., J. Darling, G. Silber, and M. Ferrari. 1980. Rare sighting of a right whale (*Eubalaena glacialis*) in Hawaii. Can. J. Zool. 58:308-312.
Salden, D.R. and J. Mickelsen. 1999. Rare sighting of a north Pacific right whale (*Eubalaena glacialis*) in Hawaii. Pacific Science 53(4):341-345.
Sanger, G. A. 1972. The recent pelagic status of the short-tailed albatross (Diomedea albatrus). Biological Conservation 4(3): 186-193.
Sangster, G. I., K. M. Lehmann, and M. Breen. 1996. Commercial fishing experiments to assess the survival of haddock and whiting after escape from four sizes of diamond mesh codends. Fish. Res. 25:323–345.
Sarti M., L., S.A. Eckert, N. García T., and A.R. Barragan. 1996. Decline of the world's largest nesting assemblage of leatherback turtles. Mar. Turtle Newsl. 74:2-5.
Sarti M., L., C. López, N. García, L. Gámez, C. Hernández, C. Ordoñez, A. Barragán, and F. Vargas. 1993. Protección e investigación de algunos aspectos biológicos y reproductivos de las tortugas marinos en la zona sur de la de la costa michoacána. Temporada 1992-93. Informe final. Facultad de Ciencias. UNAM. Mexico. 34 pp.
Scarff, J. E. 1986. Historic and present distribution of the right whale (*eubalaena glacialis*) in the eastern North Pacific south of 50"N and east of 18O"W. Reports of the International Whaling Commission (Special Issue 10):43-63.
Scarff, J. E. 1991. Historic distribution and abundance of the right whale (*Eubalaena glacialis*) in the North Pacific, Bering Sea, Sea of Okhotsk and Sea of Japan from the Maury Whale Charts. Report of the International Whaling Commission 41:467-487.
Schorr, G.S., E.A. Falcone, J. Calambokidis and R.A. Andrews. 2010. Satellite tagging of fin whales off California and Washington in 2010 to identify movement patterns, habitat use, and possible stock boundaries. Report to the Southwest Fisheries Science Center, National Marine Fisheries Service La Jolla, CA, USA.
Schweigert, J., B. McCarter, T. Therriault, L. Flostrand, C. Hrabok, P. Winchell, and D. Johannessen. 2007. Ecosystem overview: Pacific North Coast Integrated Management Area (PNCIMA), Appendix H: Pelagic fishes. Can. Tech. Rep. Fish. Aquat. Sci. 2667. Online at http://www.dfo-mpo.gc.ca/library/328842%20Appendix%20H.pdf [accessed May 2011].
Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184.
Shaw, F. R., M. E. Wilkins, K. L. Weinberg, M. Zimmermann, and R. R. Lauth. 2000. The 1998 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-114. Online at

http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-114/NOAA-TM-AFSC-114.pdf [accessed May 2011].

Sherburne, J. 1993. Status Report on the Short-tailed Albatross Diomedea albatrus. Unpublished Rep. for the U.S. Fish and Wildlife Service. Alaska Natural Heritage Program. 33pp.

Silber, G.K., M.W. Newcomer, P.C. Silber, H. Perez-Cortes M. and G.M. Ellis. 1994. Cetaceans of the Northern Gulf of California: Distribution, occurrence, and relative abundance. Mar. Mamm. Sci. 10(3): 283–298.

de Silva, G.S. 1982. The status of sea turtle populations in East Malaysia and the South China Sea. Pages 327-337 in K.A. Bjorndal (ed.), Biology and Conservation of Sea Turtles. Smithsonian Inst. Press, Washington, D. C. 583 pp.

Similä, T., J.C. Holst, and I. Christensen. 1996. Occurrence and diet of killer whales in northern Norway: seasonal patterns relative to the distribution and abundance of Norwegian spring-spawning herring. Canadian Journal of Fisheries and Aquatic Sciences, 53:769-779.

Skov, H., and coauthors. 2008. Small-scale spatial variability of sperm and sei whales in relation to oceanographic and topographic features along the Mid-Atlantic Ridge. Deep Sea Research Part Ii: Topical studies in Oceanography 55(1-2)254-268.

Smith, W. E., and R. W. Saalfeld. 1955. Studies on Columbia River smelt *Thaleichthys pacificus* (Richardson). Washington Dept. Fisheries, Olympia. Fish. Res. Pap. 1(3):3–26.

Smith, S.C., and H. Whitehead, H. 1993. Variations in the feeding success and behaviour of Galápagos sperm whales (Physeter macrocephalus) as they relate to oceanographie conditions. Canadian Journal of Zoology, 1993, 71:(10) 1991-1996, 10.1139/z93-283

Smultea, M. A., T. A. Jefferson, and A. M. Zoidis. 2010. Rare Sightings of a Bryde's Whale (Balaenoptera edeni) and Sei Whales (B. borealis) (Cetacea: Balaenopteridae) Northeast of O'ahu, Hawai'i. Pacific Science 64(3):449-457.

Spalding, D. J. 1964. Comparative feeding habits of the fur seal, sea lion and harbour seal on the British Columbia coast. Bull. Fish. Res. Board Canada 146: 1-52.

Stafford, K. M., S. L. Nieukirk, and C. G. Fox. 2001. Geographic and seasonal variation of blue whale calls in the North Pacific. Journal of Cetacean Management. 3:65-76.

Starbird, C.H., and M.M. Suarez. 1994. Leatherback sea turtle nesting on the North Vogelkop coast of Irian Jaya and the discovery of a leatherback sea turtle fishery on Kei Kecil Island. Pages 143-146 in Bjorndal, K. A. , A.B. Bolten, D. A. Johnson, and Eliazar, P. J., (compilers) Proc. of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. U.S. Dep. Commer., NOAA Tech. Memo NMFS-SEFSC-351. 323 pp.

Starbird, C., A. Baldridge, and J.T. Harvey. 1993. Seasonal occurrence of leatherback sea turtles (Dermochelys coriacea) in the Monterey Bay Region, with notes on other sea turtles, 1986-1991. Calif. Fish and Game 79(2):54-62.

Stehn, R.A., K.S. Rivera, S. Fitzgerald, and K.D. Wohl. 2001. Incidental catch of seabirds by longline fisheries in Alaska. In: Seabird bycatch: trends, roadblocks, and solutions. (Ed) E.F. Melvin and J.K. Parrish. Proceedings of the Symposium, Seabird Bycatch: Trends, Roadblocks, and Solutions, February 26-27, 1999,

Blaine, Washington, Annual Meeting of the Pacific Seabird Group. University of Alaska Sea Grant, AK-SG-01-01.
Stevick P, Allen J, Clapham P, Friday N, Katona S, Larson F, Lien J, Mattila D, Palsboll P, Sigurjonsson J, Smith T, Oien N, Hammond PS, 2003. North Atlantic humpback whale abundance and rate of increase four decades after protection from whaling. Marine Ecology-Progress Series 258:263-273.
Straley, J., O'Connell, T., Mesnick, S., Behnken, L. and Liddle, J. 2005. North Pacific Research Board Project Final Report. Sperm Whale and Longline Fisheries Interactions in the Gulf of Alaska.
Suryan, R.M. 2008. Oregon State University. Unpublished data.
Suryan, R.M., F. Sato, G.R. Balogh, K.D. Hyrenbach, P.R. Sievert, and K. Ozaki. 2006. Foraging destinations and marine habitat use of short-tailed albatross: A multi-scale approach using first-passage time analysis. Deep-Sea Research II 53 (2006) 370–386.
Suryan, R.M., G.R. Balogh, and K.N. Fischer. 2007a. Marine Habitat Use of North Pacific Albatross During the Non-breeding Season and Their Spatial and Temporal Interactions with Commercial Fisheries in Alaska. North Pacific Research Board Project 532 Final Report. 69pp.
Suryan, R.M., K.S. Dietrich, E.F. Melvin, G.R. Balogh, F. Sato, and K. Ozaki. 2007b. Migratory routes of short-tailed albatross: use of exclusive economic zones of North Pacific Rim countries and spatial overlap with commercial fisheries in Alaska. Biological Conservation 137: 450-460.
Sutcliffe, W. H., and P. F. Brodie. 1977. Whale Distributions in Nova Scotia Waters. Bedford Institute of Oceanography, Technical Report No. 722, Dartmoth, Nova Scotia.
Suuronen, P. 2005. Mortality of fish escaping trawl gears. FAO Fish. Tech. Pap. 478. FAO Rome.
Suuronen, P., J. A. Perez-Comas, E. Lehtonen,, and V. Tschernij. 1996. Size-related mortality of herring (*Clupea harengus* L.) escaping through a rigid sorting grid and trawl codend meshes. ICES J. Mar. Sci. 53:691–700.
Sydeman, W. J. and Allen, S. G. (1999), Pinniped population dynamics in central California: correlations with sea surface temperature and upwelling indices. Marine Mammal Science, 15: 446–461
Tamura, T., and coauthors. 2009. Some examinations of uncertainties in the prey consumption estimates of common minke, sei and Bryde's whales in the western North Pacific. Unpublished paper to the IWC Scientific Committee, Madeira, Portugal.
Tershy, B. R., D. Breese, and C. S. Strong. 1990. Abundance, seasonal distribution and population composition of balaenopterid whales in the Canal de Ballenas, Gulf of California, Mexico. Report of the International Whaling Commission Special Issue 12:369-375.-Individual Recognition of Cetaceans Use of Photo-Identification and Other Techniques To Estimate Population Parameters.
Tickell, W.L.N. 1975. Observations on the status of Steller's albatross (Diomedea albatrus) 1973. Bulletin of the International Council for Bird Preservation XII:125-131.
Tickell, W.L.N. 2000. Albatross. New Haven: Yale University Press.

Tillman, M. F. 1977. Estimates of population size for the North Pacific sei whale. (Balaenoptera borealis). Report of the International Whaling Commission Special Issue 1:98-106.-Sc/27/Doc 25).

Toft, J. E., Punt, A. E., & Little, L. R. (January 01, 2011). Modelling the economic and ecological impacts of the transition to individual transferable quotas in the multispecies US west coast groundfish trawl fleet. Ices Journal of Marine Science, 68, 7, 1566-1579

Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. Zoologica 19(1):1-50 plus maps.

Treacy, S. D. 1985. Feeding habits of marine mammals from Grays Harbor, Washington to Netarts Bay, Oregon. Pages 149-198 in: R. J. Beach, A. C. Geiger, S. J. Jeffries, and B. L. Troutman (eds.). Marine mammals and their interactions with fisheries of the Columbia River and adjacent waters. NWAFC Proc. Rep. 85-04.

Trites, A.W., D.G. Calkins and A.J. Winship. 2007. Diets of Steller sea lions (*Eumetopias jubatus*) in Southeast Alaska, 1993 to 1999. Fishery Bulletin 105:234-248.

Tynan C, Ainley D, Barth J, Cowles T, Pierce S, Spear L, 2005. Cetacean distributions relative to ocean processes in the northern California Current system. Deep-Sea Res II 52:145-167.

U.S. Fish and Wildlife Service (USFWS).1997. Recovery Plan for the threatened marbled murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. Portland, Oregon. 203 pp.

U.S. Fish and Wildlife Service (USFWS). 2003. Biological Opinion on the Effects of the Total Allowable Catch-Setting Process for the Gulf of Alaska and Bering Sea/Aleutian Islands Groundfish Fisheries to the Endangered Short-tailed Albatross (*Phoebastria albatrus*) and Threatened Steller's Eider (*Polysticta stelleri*), September 2003. Anchorage, AK. FWS-2003-205.

U.S. Fish and Wildlife Service (USFWS). 2004a. Biological Opinion on the Effects of the Reopened Shallow-Set Sector of the Hawaii Longline Fishery on the Short-tailed Albatross (*Phoebastria albatrus*), October 2004. Honolulu, HI. FWS 1-2-1999-F-02.2. 129 p.

U.S. Fish and Wildlife Service (USFWS). 2004b. Marbled murrelet (*Brachyramphus marmoratus*) 5-year review. U.S. Fish and Wildlife Service, Oregon Fish and Wildlife Office, Region 1, Portland, OR. 28 p.

U.S. Fish and Wildlife Service (USFWS). 2006. California least tern (*Sternula antillarum browni*) 5-Year Review Summary and Evaluation. U.S. Fish and Wildlife Service, Carlsbad, CA. 35 p.

U.S. Fish and Wildlife Service (USFWS). 2008. Short-tailed albatross Recovery Plan. Anchorage, AK, 105 pp.

U.S. Fish and Wildlife Service (USFWS). 2009a. U.S. Fish and Wildlife Service-Spotlight Species Action Plan (2010-2014). California least tern (*Sternula* (= *Sterna*) *antillarum browni*). Carlsbad Fish and Wildlife Office. U.S. Fish and Wildlife Service, Carlsbad, CA. 4 p.

U.S. Fish and Wildlife Service (USFWS). 2009b. Marbled murrelet (*Brachyramphus marmoratus*) 5-year review. U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, Lacey, WA. 108 p.

Van Eenennaam, J. P., M. A. H. Webb, X. Deng, S. I. Doroshov, R. B. Mayfield, J. J. Cech, D. C. Hillemeier, and T. E. Willson. 2001. Artificial spawning and larval rearing of Klamath River green sturgeon. Transactions of the American Fisheries Society **130**:159-165.

Visser, I. 1999. Benthic foraging on stingrays by killer whales (Orcinus orca) in New Zealand waters. Marine Mammal Science, 15:220-227.

Visser, I.N. 2000. Killer whale (Orcinus orca) interactions with longline fisheries in New Zealand waters. Aquatic Mammals 2000, 26.3, 241–252.

Von Saunder, A. and J. Barlow. 1999. A report of the Oregon, California and Washington Line-transect Experiment (ORCAWALE) conducted in west coast waters during summer/fall 1996. U.S. Dep. Commer. NOAA Tech. Memo. NMFS-SWFSC-264. 40 pp.

Wada, S. 1973. The ninth memorandum on the stock assessment of whales in the North Pacific. Rep. Int. Whal. Comm. 23:164-169.

Wada S. 1980. On the genetic uniformity of the North Pacific sperm whale. Reports of the International Whaling Commission Special Issue 2:205-211.

Wade, P. R. and Gerrodette, T. 1993. Estimates of cetacean abundance and distribution in the eastern tropical Pacific. Reports of the International Whaling Commission. 43:477-493.

Wade, P.R. and R. Angliss. 1997. Guidelines for assessing marine mammal stocks: report of the GAMMS workshop April 3-5, 1996, Seattle, Washington. U.S. Department of Commerce, NOAA Technical Memo. NMFS-OPR-12. 93 pp.

Wade, P.R., M.P. Heide-Jorgensen, K. Shelden, J. Barlow, J. Carretta, J. Durban, R. LeDuc, L. Munger, S. Rankin, A. Sauter and C. Stinchcomb. 2006. Acoustic detection and satellite tracking leads to discovery of rare concentration of endangered North Pacific right whales. Biol. Lett. 2:417-419.

Wade, P.R., A. Kennedy, R. LeDuc, J. Barlow, J. Carretta, K. Sheldon, W. Perryman, R. Pitman, K. Robertson, B. Rone, J.C. Salinas, A. Zerbini, R.L. Brownell, Jr, and P.J. Clapham. 2011. The world's smallest whale population? Biol. Lett. 7:83-85.

Waite, J. M., K. Wynne, and D. K. Mellinger. 2003. Documented sighting of a North Pacific right whale in the Gulf of Alaska and post-sighting acoustic monitoring. Northwest. Nat. 84:38-43.

Wang, P. 1978. Studies on the baleen whales in the Yellow Sea. Acta Zool. Sin. 24:269-277 .

Ward, P., Myers, R.A., and Blanchard, W. 2004. Fish lost at sea: the effect of soak time on pelagic longline catches. Fish. Bull. 102: 179-195.

Ward, E.J., E.E. Holmes, and K.C. Balcomb. 2009. Quantifying the effects of prey abundance on killer whale reproduction. Journal of Applied Ecology 46:632-640.

Waring G.T., D.L. Palka, K.D. Mullin, J.H.W. Main, L.J. Hansen, and K.D. Bisack. 1997. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments — 1996. NOAA Tech. Memo. NMFS-NE-114: 250 pp.

Waring, G. T., Quintal, J. M. and Schwartz, S. L., editors. 2001. US Atlantic and Gulf of Mexico marine mammal stock assessments- 2001. NOAA Technical Memorandum NMFS NE 168; 307p.

Waring G, Josephson E, Maze-Foley K, Rosel PE, 2009. U.S. Atlantic and Gulf of Mexico marine mammal stock assessment -- 2009. NOAA Technical Memorandum NMFS-NE-213.

Washington Sea Grant. 2011. Bringing albatross conservation to West Coast groundfish fisheries: progress on outreach efforts in the longline fleet. 24 August 2011.

Watkins, W.A., Moore, K. E., and Tyack, P. 1985. Sperm whale acoustic behaviors in the southeast Caribbean. Cetology 49:1-15.

WDF (Washington Department of Fisheries). 1993. Commercial Salmon Fishing Gears for Washington Fisheries. Olympia, WA.

WDF (Washington Department of Fisheries). 1993. Marine Fish and Shellfish Gears for Washington Fisheries. Olympia, WA.

WDFW (Washington Department of Fish and Wildlife). 2002. Fishing in Washington Sportfishing Regulations. Olympia, WA.

Weinberg, K. L., M. E. Wilkins, and T. A. Dark. 1984. The 1983 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-F/NWC-70.

Weinberg, K. L., M. E. Wilkins, R. R. Lauth, and P. A. Raymore Jr. 1994a. The 1989 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-33. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-33.pdf [accessed May 2011].

Weinberg, K. L., M. Zimmermann and R. R. Lauth. 1994b. Appendices to the 1989 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-33.

Weinberg, K. L., M. E. Wilkins, F. R. Shaw, and M. Zimmermann. 2002. The 2001 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-128. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-128.pdf [accessed May 2011].

Wetherall, J.A., G.H. Balazs, R.A. Tokunaga, and M.Y.Y. Yong. 1993. Bycatch of marine turtles in the North Pacific high-seas driftnet fisheries and impacts on the stocks. In: Ito, J. et al. (editors), INPFC Symposium on biology, distribution, and stock assessment of species caught in the high seas driftnet fisheries in theNorth Pacific Ocean, Bulletin Number 53 (III): 519-538 Int. North. Pac. Fish Comm.

Whitehead, H. 2002. Estimates of the current global population size and historical trajectory for sperm whales. Marine Ecology Progress Series 242:295-304.

Whitehead, H. 2003. Sperm Whales: social evolution in the ocean. University of Chicago Press, 431 pg.

Wiles, G. J. 2004. Washington State status report for the killer whale. Washington Department Fish and Wildlife, Olympia, Washington.

Wilkins, M. E. 1998. Appendices to the 1995 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-89. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-89a.pdf [accessed May 2011].

Wilkins, M. E., M. Zimmermann, and K. L. Weinberg. 1998. The 1995 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-89. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-89.pdf [accessed May 2011].

Wilkins, M. E., and F. R. Shaw. 2000. Appendices to the 1998 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-114. Online at http://www.afsc.noaa .gov/Publications/AFSC-TM/NOAA-TM-AFSC-114/Appendices%20to%20NOAA-TM-AFSC-114.pdf [accessed May 2011].

Wilkins, M. E., and K. L. Weinberg. 2002. Appendices to the 2001 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-128. Online at http:// www.afsc.noaa.gov/race/media/publications/archives/pubs2002/techmemo128_append.pdf [accessed May 2011].

Willson, M. F., R. H. Armstrong, M. C. Hermans, and K Koski. 2006. Eulachon: a review of biology and an annotated bibliography. Alaska Fisheries Science Center Processed Report 2006-12. Auke Bay Laboratory, Alaska Fish. Sci. Cent., NOAA, Natl. Mar, Fish. Serv., Juneau, AK. Online at http://www.afsc.noaa.gov/publications/ProcRpt/PR%202006-12.pdf [accessed March 2011].

Wilson, M.T. 2009. Ecology of small neritic fishes in the western Gulf of Alaska. I. Geographic distribution in relation to prey density and the physical environment. Mar. Ecol. Progr. Ser. 392: 223–237.

Wilson, M. T., C. M. Jump, and A. Buchheister. 2009. Ecology of small neritic fishes in the western Gulf of Alaska. II. Consumption of krill in relation to krill standing stock and the physical environment. Mar. Ecol. Progr. Ser. 392: 239–251.

Witt, M.J., R. Penrose and B.J. Godley. 2007. Spatio-temporal patterns of juvenile marine turtle occurrence in waters of the European continental shelf. Marine Biology 151:873-885

Woodhouse, C. D., and J. Strickley. 1982. Sighting of northern right whale *(Eu*balaena *glacialis)* in the Santa Barbara Channel. Journal of Mammalogy 63:701-702.

Yablokov, A. V. 1994. Validity of whaling data. Nature 367:108.

Zador, S.G., Punt, A.E., Parrish, J.K., 2008. Population impacts of endangered short-tailed albatross bycatch in the Alaskan trawl fishery. Biological Conservation 141: 872–882.

Zerbini A, Clapham P, Wade P, 2010. Assessing plausible rates of population growth in humpback whales from life-history data. Marine Biology 157:1225-1236.

Zimmermann, M. 1994. Appendices to the 1992 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-42.

Zimmermann, M., M. E. Wilkins, R. R. Lauth, and K. L. Weinberg. 1994. The 1992 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-42.

Appendix A - Evaluating Trophic Impacts of California Current Groundfish Fisheries on Protected Species

Isaac C. Kaplan
Northwest Fishery Science Center, NOAA
2725 Montlake Blvd. E.
Seattle, WA 98112
Tel. 1(206)302-2446, Fax 1(206)860-3335
Isaac.Kaplan@noaa.gov

Introduction:

This document aims to provide strategic, qualitative advice regarding the impacts of West Coast groundfish fisheries on key forage species of the California Current. The document addresses the likely impacts of a range of fishing strategies, and the effects of these strategies on forage groups such as euphausiids (krill), cephalopods (squid), and small pelagic fish (sardines, *Sardinops sagax*, and anchovies, *Engraulis mordax*). These prey groups are primary diet items for protected species, including marine mammals and birds.

The importance of euphausids, squid, and small pelagic fish as forage in the California Current is supported by a comprehensive synthesis of diet information for major taxa within the California Current ecosystem, including fish, marine mammals, birds, and invertebrates (Dufault et al. 2009). This synthesis is a compilation of 75 published diet studies from this ecosystem, and calculations of representative diets for each species or aggregated functional group. Table 1 lists diets of marine mammals and birds, as reported in Dufault et al. (2009). In particular, cephalopods comprise more than 25% of the diets of pinnipeds, toothed whales, and small cetaceans. Euphausiids comprise more than 25% of the diets of baleen whales, and are also are a smaller percentage of the diets of surface seabirds and migratory seabirds (sooty shearwaters, *Puffinus griseus*). Small pelagic fish comprise more than 25% of the diets of migratory seabirds, diving birds, surface seabirds, and juvenile pinnipeds.

Below I describe simulation results from an Atlantis ecosystem model of the California Current. The model is a spatially explicit, dynamic projection of the biomass, abundance, and weights-at-age of over 60 species or functional groups on the US West Coast (Brand et al. 2007, Kaplan and Levin 2009). The simulations involve a range of fishing scenarios, from no fishing up to levels well above current harvests. In the model, abundance of any species or group is influenced by both direct fishing mortality, and by shifts in predation mortality that may stem from fishing. We therefore expect the ecosystem model to capture both the direct and indirect effects of fishing on these forage species.

I consider the impacts of fishing on forage fish for three separate cases studies, or sets of simulations. The first case study (Kaplan and Levin 2009) explores a range of hypothetical harvest levels. The second case study investigates realistic estimates of current harvest, and potential increases in harvest over the next 5 years that may arise under an individual transferable quota program (Kaplan et al. submitted). The third case study involves a revised version of the model (Horne et al. in press), and tests a series of alternate fisheries management options such as marine protected areas and gear switching.

These cases studies illustrate that current activities of the US West Coast groundfish fisheries are unlikely to have strong negative impacts on these forage species.

Methods

The Atlantis California Current Ecosystem Model

The California Current Atlantis ecosystem model (Brand et al. 2007, Kaplan and Levin 2009) is built to address the impacts of climate, oceanography, nutrient dynamics, and spatially explicit fishing effort on a dynamic food web. The generic Atlantis code is well developed at this time, and Fulton (2001, 2004) and Fulton et al. (2005, 2007) have parameterized it for several systems in Australia. Most recently, Fulton et al. have used the SE Australia model to rank alternative policy scenarios, quantitatively evaluating alternative management packages of quotas, protected areas, closed seasons, and other policy options (Fulton et al. 2007).

Our California Current Atlantis model extends from the US/Canada Border to Point Conception, California, and out to the 1200m isobath (Figure 1). The trophic dynamics are represented by 55 functional groups in the food web. Functional groups are typically comprised of pools of 1 to 10 species with similar ecological roles. General classes of functional groups include habitat-forming species like kelp, corals and sponges, as well as vertebrate consumers, benthic invertebrates, zooplankton, phytoplankton and detritus. Vertebrate populations have age structure, and Atlantis explicitly tracks weight-at-age. The model is divided into 62 spatial zones, each with up to seven depth layers. This allows us to explicitly test hypotheses regarding fish migrations and movement behavior, fleet dynamics, and spatial management. The model is forced with daily hydrodynamic flows, salinity, and temperature outputs from a high-resolution three-dimensional Regional Ocean Modeling System (www.myroms.org), implemented by E. Curchitser and K. Hedstrom (*pers. comm., Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Road, New Brunswick, NJ 08901*), and recently applied by Hermann et al. (2009). A separate sub-module simulates simplified effort dynamics for fisheries. The full parameterization for the California Current is available in Brand et al. (2007).

Modifications since the publication of Brand et al. (2007) primarily involve addition of canary rockfish and English sole groups, minor updates to stock abundance as reported in the 2007 stock assessments (PFMC 2008), and inclusion of updated diet data (Dufault et al 2009). The new diet data are particularly important, since they dictate the links in the food web, and thus predator/prey interactions.

The revised version of the model used in the third set of simulations below (Horne et al. in press) is quite similar to the original implementation, but includes more recent estimates of biomass, a slightly different spatial geometry in Central California, and the addition of several extra functional groups (one invertebrate, one mammal, and five finfish functional groups).

Case Studies (Sets of Scenarios)

Case Study 1: Effects of hypothetical harvest levels (Kaplan and Levin 2009)

This set of simulations investigated the impact of a range of harvest levels on the California Current ecosystem, and then tested the utility of various ecosystem indicators to detect the resulting community-level effects of fishing.

The results presented here are from 25 year model runs subject to a range of fishing intensities. The initial conditions for the biological model include abundance and weight-at-age of each vertebrate group in each area, and biomass per area for all other groups. These initial conditions are based on data from approximately 1995-2005.

Fishing was parameterized based on initial abundance of each group. We identified all functional groups that are landed by US West Coast fisheries, using the PacFIN fish ticket landings database. Small pelagic fish and squid were reported in the landings, wile euphausiids were not. We then simulated the harvest of a constant amount (metric tons) of these groups per year, ranging from 0 x initial abundance to 1x initial abundance. The increments for harvest were [0 0.01 0.03 0.05 0.075 0.1 0.15 0.2 0.25 0.3 0.5 0.7 1.0] x initial abundance.

Case Study 2: Realistic estimates of current harvest and potential increases (Kaplan et al. submitted)

This set of simulations was motivated by a desire to evaluate the ecosystem impacts of increased catch of certain target species, as may occur under an individual transferable quota program for the West Coast groundfish fishery. The catch scenarios are:

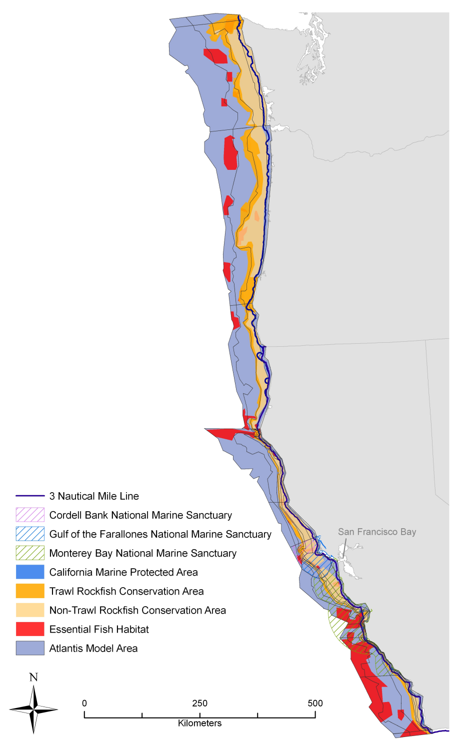
- ***Status Quo***, in which catches per species and area occur based on the assumption that regulations in the future are the same as those set between 2003 and 2006. Catches of target and bycatch species under this scenario are roughly the same as those that occurred from 2003 to 2006.
- ***Scenario 1*** (Low Catch Scenario), in which fishermen minimally increase catches of target species compared to the Status Quo scenario.
- ***Scenario 2*** (Medium Catch Scenario), in which fishermen moderately increase catch of some target species.
- ***Scenario 3*** (High Catch Scenario): fishermen substantially increase catch of some target species.
- ***No Fishing***, in which there is no catch of any species or group by any fishery.

The annual catch projections (Table A1) were applied beginning in model year 2009, with these catches imposed for 20 years (through 2028).

We converted the catch scenarios (Table A1) to annual catch estimates per functional group, and applied these catches beginning in model year 2009. This required matching regions defined in the catch projections with Atlantis regions, as well as matching the species from the catch projection to functional groups within Atlantis. For functional groups not listed in the catch scenarios (i.e. not contained in Table A1), we applied the final year of data we had from the PacFIN landings database (2004) to all projection years. Annual catches were applied in each model year as long as they did not exceed the standing stock. We did not decrease harvests if biomass declined (i.e. we did not simulate a management response).

Case Study 3: Effects of alternate fishing strategies (Horne et al. in press).

The third case study uses a revised Atlantis ecosystem model (Horne et al. in press), with the aim of considering spatial management options and the effects of alternate fishery management policies on ecosystem services. We tested fishery management scenarios that capture a range of options for spatial management and shifts in prevalence of particular fishing gears. Using the Atlantis ecosystem model, we simulated the impact of each of these scenarios for 20 years. Fishing is simulated on a per fleet basis, where a



fleet is generally a gear (e.g groundfish trawl, recreational hook and line).

For each fleet (gear), we specify

1) The proportion of each model spatial cell that is open or closed to that fleet
2) The fishing mortality (%/year) applied to each spatial cell that is open to fishing

The scenarios begin in 2010 and apply a particular combination of spatial management and fleet-specific fishing mortalities for 20 years.

Scenario 1: Status Quo

This scenario aims to evaluate the predicted performance of existing state MPAs, Rockfish Conservation Areas (RCAs), and Essential Fish Habitat (EFH) closures.

The scenario projects the Atlantis ecosystem model for 20 years, imposing fishing mortality from all existing fleets onto all relevant species or functional groups. Spatial fishing closures in the model are based on existing EFH and RCA restrictions that limit bottom contact or bottom trawl gear [1] (Figures 2 and 3). EFH and RCA closures are assumed to persist to the end of the simulation, since recovery of rockfish (*Sebastes*) stocks is expected to take several decades. Fishing mortality is apportioned between each of 20 gears.

---

[1] http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/Groundfish-EFH/upload/Map-Gfish-EFH-Close.pdf

For the groundfish gears, fishing mortality is derived from estimates of total mortality, including discards, from Bellman et al. (2008) [2]. For the non-groundfish gears, fishing mortality is based on landings reported in the PacFIN database[3]. For these simple simulations, we assume that fishing mortality (% mortality per year) remains constant over the course of the simulation. We do not vary fishing mortality or attempt to model time-varying quotas.

Scenario 2: Gear Shift

This scenario captures the desire to reduce bycatch by encouraging fishers to switch from trawl gear to “fixed gear” (pot or longline) that has lower bycatch rates. New individual quota regulations recently enacted by the Pacific Fishery Management Council allow for such gear switching [4]. Bellman et al. (2008) estimated total mortality per gear, and this can be used to parameterize a switch in gears. All details of the scenarios are the the same as Status Quo, except Scenario 2 cuts coast-wide limited entry trawl fishing mortality rates by 50%. Longline and pot fishing effort (mortality) is increased by a factor of 2.5 so that total value of landed target species remains equal to Status Quo. This results in a decrease in fishing mortality on non-target species, due to the higher selectivity of longline and pot gear.

[2] http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/TotalMortality_update2007.pdf
[3] http://www.psmfc.org/pacfin/data/r307.woc07
[4] http://www.pcouncil.org/groundfish/gffmp/gfa20/FinalAlternatives_080112.pdf

Scenario 3: Closed Area for Bottom Contact Gear

Status Quo spatial management involves an offshore RCA that prohibits trawl gear and a separate inshore RCA that prohibits non-trawl commercial gear. The offshore trawl RCA allows bottom contact gear (longline and pot) that may harm biogenic habitat. Scenario 3 converts all RCAs to prohibit all bottom contact gear (trawl, longline, and pot). As in other scenarios, RCAs will be permanent and will not vary seasonally.

No fishing scenario.

This is a 20 year run with no fishing mortality, meant to predict biomass levels for an unfished population.

Results and Discussion

Case Study 1: Effects of hypothetical harvest levels

This work from Kaplan and Levin (2009) illustrated that forage species such as small pelagic fish and squid are quite resilient to direct fishing mortality, as would be expected from their life history. Table 2 illustrates that small pelagic fish in the model did not decline under fishing mortality rates as high as 0.3 yr^{-1}, and cephalopods declined by only about half under the highest fishing mortality rates simulated here (0.7 yr^{-1}). While

11

focused stock assessments are better tools than Atlantis for precisely estimating allowable mortality rates, the simulations illustrate the high productivity of these stocks. Bycatch of these two forage species by groundfish fisheries is most likely at least an order of magnitude less than those mentioned above.

In this case study, no direct fishing mortality was imposed on large zooplankton (euphausiids), and so only indirect effects of fishing impacted them, such as changes in predation mortality. Large zooplankton abundance varied less than 4% between scenarios, with the slight increase in simulations in which their predators were heavily depleted.

Case Study 2: Realistic estimates of current harvest and potential increases

These examples predicted that changing harvest levels from Status Quo to three possible alternatives (under an individual quota program) would not impact small pelagic fish, squid, or euphausiids (Table 3). In these scenarios, there was no fishing on euphausiids, and a constant amount of fishing on squid and small pelagic fish that did not vary between scenarios. Therefore the results suggest that the changes in groundfish harvest levels tested here would not impact forage species through indirect effects (predation or competition). It should be noted that the fishing mortality rates tested here are both realistic and low, with fishing mortality rates of <5% for groundfish target species.

Comparing the results under no fishing to the four fished scenarios suggests that without fishing one could expect slightly fewer (3%) euphausiids, due to high abundances of their predators. This is similar to the relationship identified in the results for Case Study 1. Reduced fishing mortality on small pelagic fish would cause a slight increase in their abundance (~25%). The model predicts a large increase in abundance of squid in the absence of direct fishing on them (~20x), though this may be unrealistic, and further model calibration and fitting may resolve this.

Case Study 3: Effects of alternate fishing strategies

In the Horne et al. (in press) model, the Status Quo scenario, Gear Shift, and Closed Area scenarios varied management strategies for groundfish fisheries. This subsequently changed predation on forage species as well as competition, but did not change fishing mortality on forage species. Relative to Status Quo, the Gear Shift and Closed Area led to less than a 1% impact on small pelagic fish and euphausiids (Table 4). In Table 4, squid appear more abundant in the Gear Shift scenario (1.65x) and the Closed Area scenario (51x) than Status Quo, which had very low squid abundance at the end of 20 year simulation.

The No Fishing scenario here suggests that high predator abundance in the unfished situation may lead to 20% lower abundances of small pelagic fish, and as much as a 60% reduction in euphausiid abudance, relative to what would be expected under Status Quo fishing. The very high abundance of squid when they were released from direct fishing mortality (Table 4) is relative to a Status Quo case where their abundance oscillated and then declined steeply. Relative to estimates of 2009 squid biomass, in the No Fishing Scenario squid increased 313x over the course of a 20 year simulation. In reality, ceasing fishing mortality on squid is likely to lead to an increase in their abundance, but ongoing calibration of the model is likely to suggest more moderate increases.

Summary

The simulations above demonstrate the resilience and productivity of forage species, such as euphausiids, squid, and small pelagic fish. The realistic fishing scenarios tested (Case Studies 2-3) suggest that moderate and realistic alterations in the groundfish fisheries are unlikely to have strong negative impacts on these groups. All three case studies demonstrate that forage group abundance may be slightly higher under current fishing levels than in unfished scenarios, which had higher predation rates on forage species. Protected species such as marine mammals and birds, which frequently prey heavily upon these forage groups, are unlikely to be strongly impacted by food web interactions caused by groundfish fisheries.

14

References:

Brand, E. J., Kaplan, I.C., Harvey, C.J., Levin, P.S., Fulton, E.A., Hermann, A.J., and Field, J.C. 2007. A spatially explicit ecosystem model of the California Current's food web and oceanography. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-84. Available from http://www.nwfsc.noaa.gov/publications/index.cfm [accessed 14 January 2009] .

Dufault, A.M., K.M. Marshall, and I.C. Kaplan. 2009. A synthesis of diets and trophic overlap of marine species of the California Current in the Northern California Current. NOAA Technical Memorandum NMFS-NWFSC-103. Available online: http://www.nwfsc.noaa.gov/assets/25/ 7024_12212009_134730_DietsCalCurrentTM103WebFinal.pdf

Fulton, E. A. 2001. The effects of model structure and complexity on the behavior and performance of marine ecosystem models. Doctoral thesis, University of Tasmania, Hobart, Tasmania, Australia.

Fulton, E. A. 2004. Biogeochemical marine ecosystem models II: The effect of physiological detail on model performance. Ecol. Model. 173,371–406.

Fulton, E. A., Punt, A.E., and Smith, A.D.M. 2005. Which ecological indicators can robustly detect effects of fishing? ICES J. Mar. Sci. 62,540–551.

Fulton, E.A., Smith, A.D.M., and Smith, D.C. 2007. Alternative Management Strategies for Southeast AustralianCommonwealth Fisheries: Stage 2: Quantitative Management Strategy Evaluation. Australian Fisheries Management Authority, Fisheries Research and Development Corporation. Available from http://atlantis.cmar.csiro.au/ [accessed 5 October 2009].

Hermann, A. J., Curchitser, E.N., Haidvogel, D. B. and Dobbins, E.L. 2009. A comparison of remote versus local influence of El Nino on the coastal circulation of the Northeast Pacific. Deep Sea Research II., in press.

Horne. P, I. C. Kaplan, C. J. Harvey, P. S. Levin, and E. A. Fulton. In press. An ecsosystem model of the California Current, focusing on Central California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-XXXXX.

Kaplan, I.C., P.S. Levin, M. Burden, and E.A. Fulton. Submitted to Canadian Journal of Fisheries and Aquatic Science. Fishing Catch Shares in the Face of Global Change: A Framework for Integrating Cumulative Impacts and Single Species Management .

Kaplan, I.C., and Levin, P.S. 2009. Ecosystem based management of what? An emerging approach for balancing conflicting objectives in marine resource management.In R.J. Beamish and B.J. Rothschild, eds. The Future of Fisheries In North America. Springer, NY 736 pages.

Pacific Coast Fisheries Information Network (PacFIN). 1981-2009 W-O-C All Species Reports(Rpt #307). Available from http://www.psmfc.org/pacfin/data/r307.woc08 [accessed 17 May 2009] .

Pacific Fishery Management Council (PFMC). 2003. Minutes of the 170th meeting of the Pacific Fishery Management Council: Bycatch Model Review Workshop Report. 7700 NE Ambassador Place, Suite 101, Portland OR 97220.

Pacific Fishery Management Council (PFMC). 2008. Pacific Coast Groundfish Fishery Stock Assessment and Fishery Evaluation, Volume 1. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, OR 97220. Available from http://www.pcouncil.org/groundfish /gfsafe0308/SAFE_2008_March.pdf [accessed 17 May 2009]

Pacific Fishery Management Council (PFMC) and National Marine Fisheries Service (NMFS). 2009. Proposed Acceptable Biological Catch and Optimum Yield Specifications and Management Measures for the 2009-2010 Pacific Coast Groundfish Fishery Final Environmental Impact Statement Including Regulatory Impact Review and Initial Regulatory Flexibility Analysis. Pacific Fishery Management Council, Portland, OR. January 2009. Available from http://www.pcouncil.org/groundfish/gfspex/gfspex09-10.html [accessed 17 May 2009]

17

Table 1. Diets of marine mammal and bird groups in the California Current. From Dufault et al. (in prep). The first column lists prey items, the second column is adult diet composition (% wet weight), and third column is juvenile diet composition.

Baleen whale		
	Adult	Juvenile
Large zooplankton	0.3539	0.3539
Small planktivores	0.0501	0.0501
Deep vertical migrators	0.0049	0.0049
Cephalopods	0.0049	0.0049
Deposit feeders	0.5863	0.5863
Sea otters		
	Adult	Juvenile
Other benthic filter feeders	0.5760	0.5760
Benthic herbivorous grazers	0.2596	0.2596
Deep macrozoobenthos	0.0008	0.0008
Megazoobenthos	0.1631	0.1631
Shallow macrozoobenthos	0.0005	0.0005
Pinnipeds (seals, sea lions)		
	Adult	Juvenile
Deposit feeders	0.0000	0.0214
Shallow macrozoobenthos	0.0000	0.0172
Cephalopods	0.4531	0.3719
Shallow small rockfish	0.0068	0.0000
Juv. shallow small rockfish	0.0000	0.0005
Deep small rockfish	0.0384	0.0000
Juv. Deep small rockfish	0.0000	0.0034
Deep misc. fish	0.0000	0.0616
Misc. nearshore fish	0.0000	0.0207
Juv. small flatfish	0.0000	0.0212
Deep large rockfish	0.0109	0.0000
Juv. Deep large rockfish	0.0000	0.0012
Midwater rockfish	0.0358	0.0000
Juv. midwater rockfish	0.0000	0.0041
Hake	0.0967	0.0000
Juv. Hake	0.1035	0.0428
Sablefish	0.0046	0.0000
Juv. Sablefish	0.0000	0.0086
Large planktivores	0.0018	0.0000
Small planktivores	0.1214	0.3196
Salmon	0.0116	0.0000
Juv. Salmon	0.0000	0.0482
Juv. small demersal sharks	0.0550	0.0311
Shallow large rockfish	0.0054	0.0000
Juv. shallow large rockfish	0.0000	0.0006
Juv. skates and rays	0.0550	0.0199
Gelatinous zooplankton	0.0000	0.0060

18

Table 1 continued.

Toothed whale		
	Adult	Juvenile
Deposit feeders	0.0316	0.0316
Megazoobenthos	0.0316	0.0316
Cephalopods	0.6740	0.6740
Small planktivores	0.0236	0.0236
Large planktivores	0.0236	0.0236
Deep vertical migrators	0.0724	0.0724
Hake	0.0397	0.0397
Sablefish	0.0000	0.0000
Salmon	0.0639	0.0639
Large flatfish	0.0001	0.0001
Deep misc. fish	0.0397	0.0397
Shallow large rockfish	0.0000	0.0000
Migrating seabirds (sooty shearwaters)		
	Adult	Juvenile
Small planktivores	0.5786	0.5786
Large zooplankton	0.0347	0.0347
Cephalopods	0.0720	0.0720
Juv. Hake	0.0813	0.0813
Deep misc. fish	0.0227	0.0227
Deep vertical migrators	0.1293	0.1293
Juv. shallow small rockfish	0.0039	0.0039
Juv. Deep small rockfish	0.0271	0.0271
Juv. canary rockfish	0.0028	0.0028
Juv. midwater rockfish	0.0327	0.0327
Juv. shallow large rockfish	0.0050	0.0050
Juv. Deep large rockfish	0.0099	0.0099
Small cetaceans (porpoise, dolphins)		
	Adult	Juvenile
Deposit feeders	0.0276	0.0276
Megazoobenthos	0.0276	0.0276
Cephalopods	0.3334	0.3334
Deep vertical migrators	0.1580	0.1580
Misc. nearshore fish	0.0710	0.0710
Misc. nearshore fish	0.0710	0.0710
Hake	0.0710	0.0710
Large planktivores	0.0847	0.0847
Small planktivores	0.0847	0.0847
Salmon	0.0710	0.0710

Table 1 continued.

Diving seabirds (murres, auklets, cormorants)		
	Adult	Juvenile
Cephalopods	0.1016	0.1016
Deep vertical migrators	0.0755	0.0755
Shallow small rockfish	0.0466	0.0466
Juv. shallow small rockfish	0.0173	0.0173
Deep misc. fish	0.0084	0.0084
Misc. nearshore fish	0.0910	0.0910
Small flatfish	0.0337	0.0337
Misc. nearshore fish	0.0000	0.0000
Juv. midwater rockfish	0.1117	0.1117
Hake	0.0395	0.0395
Juv. canary rockfish	0.0095	0.0095
Small planktivores	0.3549	0.3549
Salmon	0.0091	0.0091
Shrimp	0.0019	0.0019
Juv. shallow large rockfish	0.0170	0.0170
Surface seabirds (gulls, pelicans, petrels)		
	Adult	Juvenile
Other benthic filter feeders	0.0200	0.0200
Cephalopods	0.1193	0.1193
Carrion	0.0608	0.0608
Juv. shallow small rockfish	0.0063	0.0063
Juv. deep small rockfish	0.0444	0.0444
Juv. misc. nearshore fish	0.0268	0.0268
Juv. deep large rockfish	0.0163	0.0163
Juv. midwater rockfish	0.0536	0.0536
Juv. Hake	0.0439	0.0439
Small planktivores	0.5130	0.5130
Juv. shallow large rockfish	0.0082	0.0082
Gelatinous zooplankton	0.0264	0.0264
Large zooplankton	0.0610	0.0610
Transient orcas		
	Adult	Juvenile
Pinnipeds	0.7890	0.7890
Toothed whale	0.0494	0.0494
Baleen whale	0.0893	0.0893
Small cetaceans	0.0709	0.0709
Diving seabirds	0.0001	0.0001
Sea otters	0.0012	0.0012

20

Table 2. *Case Study 1. Biomass at the end of 25 year simulation, relative to initial (2009) biomass. Forage species values are bold.*

	Fishing Mortality Rate on Harvested Species										
Functional Group	**0**	**0.01**	**0.03**	**0.05**	**0.075**	**0.1**	**0.15**	**0.2**	**0.3**	**0.5**	**0.7**
Large planktivores (mackerel)	1.10	1.05	1.03	1.01	0.98	0.94	0.85	0.71	0.00	0.00	0.00
Canary rockfish	3.67	4.02	3.73	4.10	3.84	4.24	3.86	4.23	4.26	3.60	3.92
Small pelagic fish (sardine, anchovy)	**1.57**	**1.52**	**1.53**	**1.48**	**1.46**	**1.40**	**1.36**	**1.24**	**1.12**	**0.00**	**0.00**
Large flatfish (arrowtooth)	0.87	0.80	0.74	0.62	0.53	0.27	0.00	0.00	0.00	0.00	0.00
Lg. demersal predators (lingcod)	2.66	2.50	2.25	1.95	1.33	0.00	0.00	0.00	0.00	0.00	0.00
Salmon	5.89	5.89	2.30	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Large pelagic predators (tuna)	52.18	52.00	52.07	51.88	51.90	51.65	51.51	51.02	50.06	45.69	45.21
Shearwaters	9.44	9.91	9.40	9.86	9.35	9.80	9.24	9.57	9.22	5.30	5.40
Hake	1.06	1.11	1.05	1.10	1.04	1.08	1.01	1.03	0.97	0.89	0.85
Sablefish	1.25	1.24	1.20	1.14	1.02	0.99	0.91	0.80	0.51	0.17	0.13
Deep vert.migrators (myctophids)	1.78	1.74	1.78	1.75	1.78	1.75	1.79	1.75	1.81	1.77	1.79
Deep misc. fish (slickhead, eelpout)	0.65	0.53	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Misc. nearshore fish (croaker, sculpin)	0.40	0.34	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Midwater rockfish	2.62	2.63	2.48	2.44	2.11	1.52	0.00	0.00	0.00	0.00	0.00
English sole	0.88	0.87	0.88	0.88	0.90	0.93	0.97	0.97	0.99	0.99	1.05
Shallow small rockfish	0.28	0.26	0.22	0.21	0.21	0.20	0.19	0.17	0.00	0.00	0.00
Deep small rockfish (longspine)	0.82	0.74	0.54	0.42	0.39	0.35	0.23	0.00	0.00	0.00	0.00
Deep large rockfish (shortspine)	1.11	1.00	0.73	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Small flatfish (petrale, dover etc)	1.27	1.16	0.97	0.82	0.67	0.41	0.00	0.00	0.00	0.00	0.00
Small demersal sharks (dogfish)	1.35	1.26	1.07	0.89	0.64	0.38	0.00	0.00	0.00	0.00	0.00
Lg. demersal sharks (sixgill etc)	0.87	0.86	0.86	0.85	0.86	0.84	0.85	0.83	0.82	0.82	0.81
Pelagic sharks	1.95	1.89	1.66	1.50	1.07	0.15	0.00	0.00	0.00	0.00	0.00
Shallow large rockfish	1.58	1.52	1.41	1.34	1.22	1.11	0.91	0.81	0.60	0.07	0.00
Skates and rays	1.42	1.29	1.06	0.82	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Surface feed birds (gulls)	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.30	1.06	1.06
Diving birds	1.15	1.14	1.15	1.14	1.15	1.15	1.15	1.14	1.13	0.80	0.78

Pinnipeds	3.90	3.90	3.89	3.88	3.86	3.85	3.83	3.80	3.74	3.31	3.30
Transient orcas	2.30	2.44	2.30	2.44	2.30	2.44	2.30	2.44	2.44	2.29	2.43
Baleen whales	1.37	1.40	1.37	1.40	1.37	1.40	1.37	1.40	1.40	1.37	1.40
Toothed whales	2.42	2.56	2.42	2.56	2.41	2.55	2.41	2.54	2.54	2.39	2.53
Otters	8.08	8.50	8.08	8.50	8.08	8.50	8.07	8.50	8.49	8.07	8.49
Squid	**2.46**	**2.52**	**2.35**	**2.39**	**2.18**	**2.10**	**1.71**	**1.51**	**1.21**	**0.46**	**0.43**
Shallow benthic filter feeders	86.62	92.95	86.64	92.97	86.68	93.02	86.80	93.10	93.46	87.26	94.73
Other benthic filter feeders	0.72	0.81	0.72	0.81	0.72	0.82	0.73	0.82	0.83	0.78	0.86
Deep benthic filter feeders	0.86	0.85	0.86	0.86	0.86	0.86	0.87	0.86	0.87	0.88	0.88
Urchins	11.90	11.89	11.90	11.89	11.90	11.89	11.90	11.89	11.89	11.89	11.88
Deep macrozoobenthos	0.93	0.92	0.93	0.92	0.93	0.92	0.93	0.92	0.92	0.98	0.96
Large crabs	2.31	2.33	2.30	2.32	2.29	2.31	2.27	2.31	2.30	2.38	2.34
Octopus	0.15	0.14	0.15	0.14	0.16	0.14	0.16	0.15	0.15	0.17	0.16
Shrimp	0.83	0.81	0.83	0.81	0.84	0.83	0.86	0.85	0.85	0.85	0.83
Large zooplankton (euphausiid)	**1.20**	**1.23**	**1.20**	**1.23**	**1.21**	**1.23**	**1.21**	**1.23**	**1.23**	**1.25**	**1.24**
Deposit feeders	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macroalgae (kelp)	0.27	0.27	0.27	0.27	0.27	0.27	0.28	0.27	0.27	0.28	0.27
Seagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carnivorous infauna	0.16	0.15	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Gelatinous zooplankton	4.04	3.90	3.77	3.61	3.41	3.19	2.74	2.27	1.53	0.04	0.03
Large phytoplankton	4.94	5.06	4.98	5.12	5.04	5.20	5.14	5.36	5.48	6.41	6.29
Small phytoplankton	3.51	4.17	3.42	4.03	3.30	3.82	3.07	3.39	3.05	1.17	1.25
Mesozooplankton (copepods)	7.72	7.32	7.69	7.29	7.66	7.26	7.60	7.19	7.20	6.71	6.99
Microzooplankton	2.74	2.62	2.73	2.61	2.73	2.61	2.73	2.61	2.61	3.15	3.09
Pelagic bacteria	12.02	12.20	12.01	12.18	11.98	12.15	11.95	12.09	12.02	12.39	12.10
Benthic bacteria	17.89	18.24	17.85	18.17	17.80	18.08	17.69	17.95	17.88	18.41	18.09
Meiobenthos	0.76	0.73	0.76	0.73	0.76	0.73	0.75	0.72	0.73	0.87	0.85
Labile detritus	0.25	0.26	0.25	0.26	0.25	0.26	0.25	0.25	0.25	0.26	0.26
Refractory detritus	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Carrion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dissolved inorganic N	0.99	0.99	0.99	0.98	0.99	0.98	0.99	0.98	0.98	0.99	0.98

369

369

24

Table 3. Case Study 2: *Biomass of functional groups at year 20, for each harvest scenario. Biomass is relative to biomass at year 20 in the Status Quo harvest. Forage species values are bold.*

Functional Group	Status Quo	Scen. 1	Scen. 2	Scen. 3	No Fishing
Large planktivores (mackerel)	1.00	1.00	1.00	1.00	1.01
Canary rockfish	1.00	1.00	1.01	1.01	1.02
Small pelagic fish (sardine, anchovy)	**1.00**	**1.00**	**1.00**	**1.00**	**1.23**
Large flatfish (arrowtooth)	1.00	0.67	0.67	0.68	1.94
Chilipepper rockfish	1.00	1.00	0.37	0.37	1.00
Lg. demersal predators (lingcod)	1.00	1.00	0.16	0.00	1.51
Salmon	1.00	1.00	1.00	1.00	1.01
Large pelagic predators (tuna)	--	--	--	--	--
Shearwaters	1.00	1.00	1.00	1.00	1.00
Hake	1.00	1.00	1.00	1.00	10.47
Sablefish	1.00	1.00	1.00	1.00	1.29
Deep vert.migrators (myctophids)	1.00	1.00	1.00	1.00	1.00
Deep misc. fish (slickhead, eelpout)	1.00	1.00	1.00	1.00	1.03
Misc. nearshore fish (croaker, sculpin)	1.00	1.01	1.02	1.02	0.99
Midwater rockfish	1.00	1.00	1.00	0.00	5.79
Bocaccio rockfish	1.00	1.00	0.94	0.94	1.08
English sole	1.00	0.92	0.85	0.85	0.98
Shallow small rockfish	1.00	1.00	1.00	1.00	1.07
Deep small rockfish (longspine)	1.00	0.94	0.94	0.94	1.02
Deep large rockfish (shortspine)	1.00	0.94	0.93	0.93	1.06
Small flatfish (petrale, dover etc)	1.00	0.91	0.89	0.82	1.13
Small demersal sharks (dogfish)	1.00	1.00	1.00	1.00	4.00
Lg. demersal sharks (sixgill etc)	1.00	1.00	1.00	1.00	1.00
Pacific Ocean perch	--	--	--	--	--
Pelagic sharks	1.00	1.00	1.00	1.00	1.01
Shallow large rockfish	1.00	1.00	1.00	1.00	1.06
Skates and rays	1.00	1.00	1.00	1.01	2.58
Surface feed birds (gulls)	1.00	0.99	0.98	0.98	1.04
Diving birds	1.00	1.00	1.00	1.00	1.00
Pinnipeds	1.00	1.00	1.00	1.00	1.00
Transient orcas	1.00	1.00	1.00	1.00	1.00
Baleen whales	1.00	1.00	1.00	1.00	1.00
Widow rockfish	1.00	1.00	1.00	0.98	1.01
Toothed whales	1.00	1.00	1.00	1.00	1.00
Otters	1.00	1.00	1.00	1.00	0.99
Squid	**1.00**	**1.00**	**1.00**	**1.00**	**21.10**
Shallow benthic filter feeders	1.00	1.01	1.02	1.02	0.89
Other benthic filter feeders	1.00	1.01	1.01	1.01	0.97
Deep benthic filter feeders	1.00	1.00	1.00	1.00	0.99
Urchins	1.00	1.00	1.01	1.02	1.00
Deep macrozoobenthos	1.00	1.00	1.02	1.01	0.83

25

Large crabs	--	--	--	--	--
Octopus	1.00	1.00	1.00	1.00	0.97
Shrimp	1.00	1.00	1.00	1.00	1.67
Large zooplankton (euphausid)	**1.00**	**1.00**	**1.00**	**1.00**	**0.97**
Deposit feeders	--	--	--	--	--
Macroalgae (kelp)	1.00	1.00	1.00	1.00	1.01
Seagrass	1.00	1.00	1.00	1.00	1.00
Carnivorous infauna	1.00	1.00	1.00	1.00	1.00
Gelatinous zooplankton	1.00	1.00	1.00	1.00	1.00
Large phytoplankton	1.00	1.00	1.00	1.00	0.97
Small phytoplankton	1.00	1.00	1.00	1.00	1.00
Mesozooplankton (copepods)	1.00	1.00	1.00	1.00	1.00
Microzooplankton	1.00	1.01	1.01	1.00	0.99
Pelagic bacteria	1.00	1.02	1.03	1.03	0.79
Benthic bacteria	1.00	1.02	1.08	1.05	0.41
Meiobenthos	1.00	1.01	1.06	1.03	0.45
Labile detritus	1.00	1.02	1.08	1.05	0.40
Refractory detritus	1.00	1.02	1.08	1.03	0.35
Carrion	1.00	1.00	1.00	1.00	1.00
Dissolved inorganic N	1.00	1.00	1.00	1.00	1.00

Table 4. Case Study 3: *Biomass of functional groups at year 20, for each management scenario. Biomass is relative to biomass at year 20 in the Status Quo harvest. Forage species values are bold.*

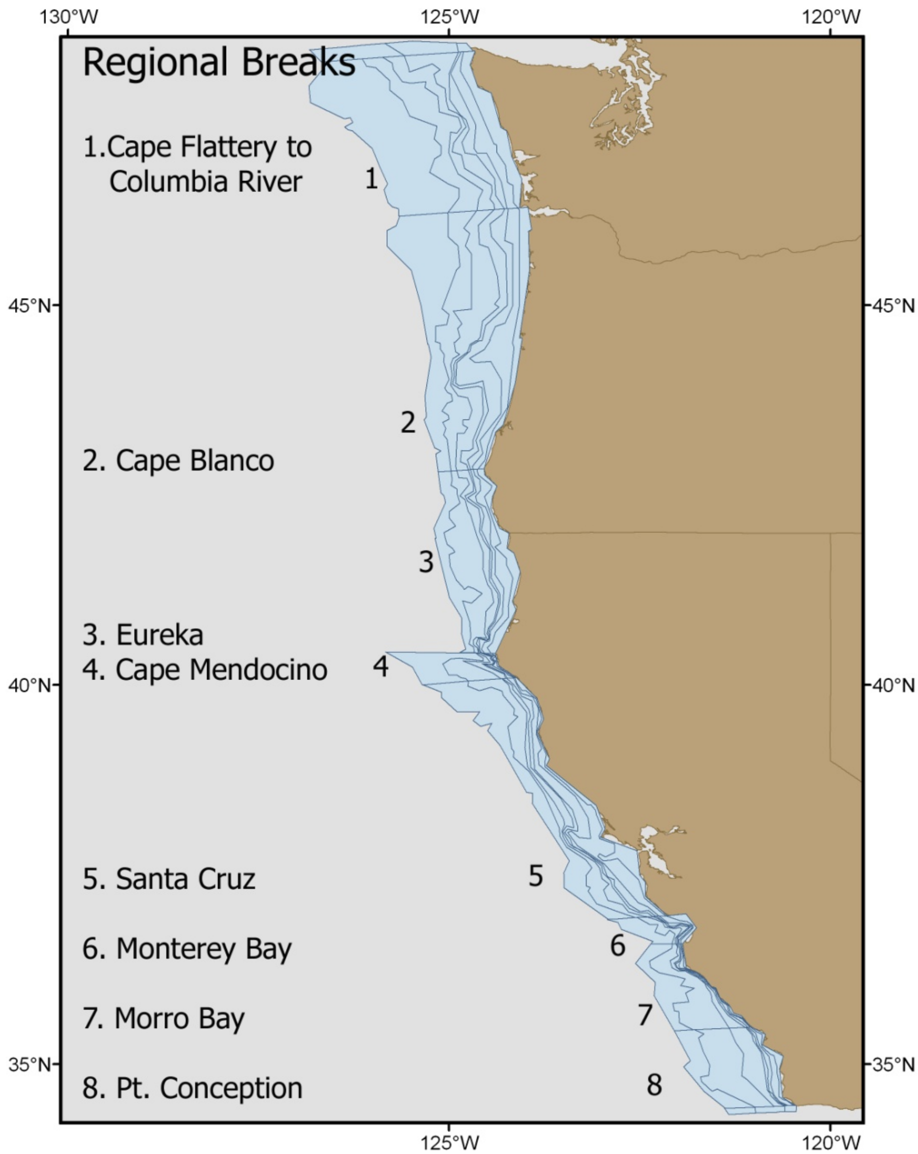
	Status Quo	**Gear Shift**	**Closed Area**	**No Fishing**
Large planktivores (mackerel)	1.00	1.02	1.13	0.98
Canary rockfish	1.00	1.02	1.11	0.85
Small pelagic fish (sardine, anchovy)	**1.00**	**1.00**	**1.01**	**0.80**
Large flatfish (arrowtooth)	1.00	1.27	1.58	1.68
Shortbelly rockfish	1	1.00	1.00	3.00
Lg. demersal predators (lingcod)	1	1.03	1.07	1.20
Salmon	1	1.04	1.21	1.29
Large pelagic predators (tuna)	1	1.00	1.00	1.23
Shearwaters	1	1.00	1.00	1.00
Hake	1	1.01	1.06	1.94
Sablefish	1	0.84	1.09	1.50
Deep vert.migrators (myctophids)	1	1.00	1.00	0.81
Deep misc. fish (slickhead, eelpout)	1	1.02	1.00	1.18
Misc. nearshore fish (croaker, sculpin)	1	0.97	1.08	0.55
Midwater rockfish	1	1.00	1.01	1.45
Surfperch and misc.	1	1.01	1.14	2.47
English sole	1	1.11	0.99	0.99
Shallow small rockfish	1	1.08	1.51	0.58
Deep small rockfish (longspine)	1	1.02	1.02	0.85
Deep large rockfish (shortspine)	1	1.03	1.05	1.04
Small flatfish (petrale, dover etc)	1	1.03	1.11	0.86
Small demersal sharks (dogfish)	1	1.03	1.18	1.02
Lg. demersal sharks (sixgill etc)	1	1.02	1.16	1.25
Yelloweye and cowcod	1	1.03	1.06	1.17
Pelagic sharks	1	1.00	1.03	2.36
Shallow large rockfish	1	1.10	1.66	1.12
Skates and rays	1	1.03	1.20	1.04
Surface feed birds (gulls)	1	1.00	1.00	0.88
Diving birds	1	1.01	1.10	0.98
Pinnipeds	1	1.00	1.00	1.05
Transient orcas	1	1.00	1.00	1.00
Baleen whales	1	1.00	1.00	1.04
Small whales and dolphins	1	1.00	1.03	1.13
Toothed whales	1	1.00	1.00	1.10
Otters	1	1.00	1.00	1.00
Squid	**1**	**1.65**	**50.93**	**63676.19**
Shallow benthic filter feeders	1	1.00	1.00	0.86
Other benthic filter feeders	1	1.00	0.99	0.90
Deep benthic filter feeders	1	1.02	1.21	2.59
Urchins	1	1.00	0.99	1.63
Deep macrozoobenthos	1	1.00	0.99	0.93

Large crabs	1	1.05	1.60	9.51
Octopus	1	1.00	1.01	0.97
Shrimp	1	1.25	2.54	0.01
Large zooplankton (euphausid)	**1**	**1.00**	**1.01**	**0.43**
Deposit feeders	1	1.01	1.14	1.35
Macroalgae (kelp)	1	1.00	1.00	0.96
Seagrass	1	1.00	1.00	1.00
Carnivorous infauna	1	1.00	1.02	0.99
Gelatinous zooplankton	1	0.99	0.99	0.99
Large phytoplankton	1	0.99	1.00	0.92
Small phytoplankton	1	1.00	1.00	0.09
Mesozooplankton (copepods)	1	0.96	1.02	1.03
Microzooplankton	1	1.00	0.99	1.44
Pelagic bacteria	1	1.00	1.03	0.49
Benthic bacteria	1	1.00	1.03	0.80
Meiobenthos	1	1.01	1.16	2.60
Labile detritus	1	1.00	1.00	0.72
Refractory detritus	1	1.03	1.23	1.18
Carrion	0	0	0	0
Dissolved inorganic N	1	1.00	1.00	1.03

28

Figure 1. Spatial extent of the California Current Atlantis model. The region includes 62 spatial boxes (green), ranging from the coastline to 2400m. This spatial configuration applies to Brand et al. (2007), Kaplan and Levin (2009), and Kaplan et al. (submitted).

.



385

385

Appendix

Table A1. *Alternative catch scenarios under individual quota, for Case Study 2. Catches of species in bold font vary between scenarios, with lowest catches in Status Quo and highest catches in Scenario 3. Catches are in metric tons per year.*

Status Quo: No improvement in targeting ability							
	North of 40° 10' N		40° 10'N to 36°N		South of 36°N		Total
	Shelf	Slope	Shelf	Slope	Shelf	Slope	
Sablefish	1,038.45	3,115.35	395.00	1,185.00	50.00	150.00	5,933.80
Longspine thornyhead	**-**	**614.00**	**-**	**210.00**	**-**	**14.00**	**838.00**
Shortspine thornyhead	**90.00**	**510.00**	**23.55**	**133.45**	**22.05**	**124.95**	**904.00**
Dover sole	**1,218.75**	**3,656.25**	**325.00**	**975.00**	**81.25**	**243.75**	**6,500.00**
Arrowtooth flounder	**2,240.00**	**960.00**	**5.11**	**2.19**	**-**	**-**	**3,207.30**
Petrale sole	756.00	1,134.00	180.00	270.00	40.00	60.00	2,440.00
Other flatfish	**1,171.50**	**-**	**328.02**	**-**	**62.48**	**-**	**1,562.00**
Yellowtail rockfish	**51.40**	**-**	**-**	**-**	**-**	**-**	**51.40**
Chilipepper rockfish	**-**	**-**	**17.80**	**-**	**-**	**-**	**17.80**
Slope rockfish	**21.40**	**192.60**	**12.00**	**108.00**	**4.80**	**43.20**	**382.00**
Dogfish	450.00	-	-	-	-	-	450.00
Pacific cod	**400.00**	**-**	**-**	**-**	**-**	**-**	**400.00**
Lingcod	**240.00**	**60.00**	**40.00**	**10.00**	**12.00**	**3.00**	**365.00**
Canary rockfish	34.20	3.80	5.40	0.60	-	-	44.00
Pac. Ocean perch	**-**	**75.00**	**-**	**-**	**-**	**-**	**75.00**
Darkblotch rockfish	**34.50**	**195.50**	**4.96**	**28.08**	**-**	**-**	**263.04**
Widow rockfish	**221.00**	**39.00**	**17.00**	**3.00**	**-**	**-**	**280.00**
Bocaccio	**-**	**-**	**63.00**	**7.00**	**-**	**-**	**70.00**
Yelloweye rockfish	9.00		4.00				13.00
Pacific whiting	115,401.25	115,401.25	6,073.75	6,073.75			242,950.00

32

Scenario 1: Pessimistic about improvements in targeting ability							
	North of 40° 10'N		40° 10'N to 36°N		South of 36°N		Total
	Shelf	Slope	Shelf	Slope	Shelf	Slope	
Sablefish	1,038.45	3,115.35	395.00	1,185.00	50.00	150.00	5,933.80
Longspine thornyhead	**-**	**1,314.09**	**-**	**756.41**	**-**	**180.00**	**2,250.50**
Shortspine thornyhead	**175.70**	**995.62**	**67.50**	**382.50**	**33.00**	**187.00**	**1,841.32**
Dover sole	**2,495.62**	**7,486.85**	**462.50**	**1,387.50**	**50.00**	**150.00**	**12,032.47**
Arrowtooth flounder	**3,454.92**	**1,480.68**	**5.11**	**2.19**	**-**	**-**	**4,942.90**
Petrale sole	756.00	1,134.00	180.00	270.00	40.00	60.00	2,440.00
Other flatfish	**2,300.00**	**-**	**700.00**	**-**	**170.00**	**-**	**3,170.00**
Yellowtail rockfish	**51.40**	**-**	**-**	**-**	**-**	**-**	**51.40**
Chilipepper rockfish	**-**	**-**	**17.80**	**-**	**-**	**-**	**17.80**
Slope rockfish	**41.33**	**371.99**	**21.79**	**196.09**	**10.00**	**90.00**	**731.20**
Dogfish	450.00	-	-	-	-	-	450.00
Pacific cod	**723.40**	**-**	**-**	**-**	**-**	**-**	**723.40**
Lingcod	**240.00**	**60.00**	**40.00**	**10.00**	**12.00**	**3.00**	**365.00**
Canary rockfish	34.20	3.80	5.40	0.60	-	-	44.00
Pac. ocean perch	**-**	**75.00**	**-**	**-**	**-**	**-**	**75.00**
Darkblotch rockfish	**34.50**	**195.50**	**4.96**	**28.08**	**-**	**-**	**263.04**
Widow rockfish	**255.00**	**45.00**	**17.00**	**3.00**	**-**	**-**	**320.00**
Bocaccio	**-**	**-**	**63.00**	**7.00**	**-**	**-**	**70.00**
Yelloweye rockfish	9.00		4.00				13.00
Pacific whiting	115,401.25	115,401.25	6,073.75	6,073.75			242,950.00

Scenario 2: Moderate improvements in targeting ability							
	North of 40° 10'N		40° 10'N to 36°N		South of 36°N		Total
	Shelf	Slope	Shelf	Slope	Shelf	Slope	
Sablefish	1,038.45	3,115.35	395.00	1,185.00	50.00	150.00	5,933.80
Longspine thornyhead	**-**	**1,314.09**	**-**	**756.41**	**-**	**180.00**	**2,250.50**
Shortspine thornyhead	**175.70**	**995.62**	**67.50**	**382.50**	**33.00**	**187.00**	**1,841.32**
Dover sole	**2,495.62**	**7,486.85**	**462.50**	**1,387.50**	**50.00**	**150.00**	**12,032.47**
Arrowtooth flounder	**3,454.92**	**1,480.68**	**5.11**	**2.19**	**-**	**-**	**4,942.90**
Petrale sole	756.00	1,134.00	180.00	270.00	40.00	60.00	2,440.00
Other flatfish	**3,721.30**	**-**	**1,078.70**	**-**	**170.00**	**-**	**4,970.00**
Yellowtail rockfish	**51.40**	**-**	**-**	**-**	**-**	**-**	**51.40**
Chilipepper rockfish	**-**	**-**	**2,000.00**	**-**	**-**	**-**	**2,000.00**
Slope rockfish	**72.03**	**648.26**	**37.97**	**341.74**	**10.00**	**90.00**	**1,200.00**
Dogfish	450.00	-	-	-	-	-	450.00
Pacific cod	**1,200.00**	**-**	**-**	**-**	**-**	**-**	**1,200.00**
Lingcod	**574.68**	**143.67**	**65.32**	**16.33**	**12.00**	**3.00**	**815.00**
Canary rockfish	34.20	3.80	5.40	0.60	-	-	44.00
Pac. ocean perch	**-**	**150.00**	**-**	**-**	**-**	**-**	**150.00**
Darkblotch rockfish	**39.35**	**222.97**	**5.65**	**32.03**	**-**	**-**	**300.00**
Widow rockfish	**255.00**	**45.00**	**17.00**	**3.00**	**-**	**-**	**320.00**
Bocaccio	**-**	**-**	**108.00**	**12.00**	**-**	**-**	**120.00**
Yelloweye rockfish	9.00		4.00				13.00
Pacific whiting	115,401.25	115,401.25	6,073.75	6,073.75			242,950.00

Scenario 3: Optimistic about improvements in targeting ability							
	North of 40° 10’ N		40° 10’N to 36°N		South of 36°N		Total
	Shelf	Slope	Shelf	Slope	Shelf	Slope	
Sablefish	1,038.45	3,115.35	395.00	1,185.00	50.00	150.00	5,933.80
Longspine thornyhead	**-**	**1,314.09**	**-**	**756.41**	**-**	**180.00**	**2,250.50**
Shortspine thornyhead	**175.70**	**995.62**	**67.50**	**382.50**	**33.00**	**187.00**	**1,841.32**
Dover sole	**3,422.21**	**10,266.64**	**634.22**	**1,902.66**	**68.56**	**205.69**	**16,500.00**
Arrowtooth flounder	**3,454.92**	**1,480.68**	**5.11**	**2.19**	**-**	**-**	**4,942.90**
Petrale sole	756.00	1,134.00	180.00	270.00	40.00	60.00	2,440.00
Other flatfish	**3,721.30**	**-**	**1,078.70**	**-**	**170.00**	**-**	**4,970.00**
Yellowtail rockfish	**1,000.00**	**-**	**-**	**-**	**-**	**-**	**1,000.00**
Chilipepper rockfish	**-**	**-**	**2,000.00**	**-**	**-**	**-**	**2,000.00**
Slope rockfish	**72.03**	**648.26**	**37.97**	**341.74**	**10.00**	**90.00**	**1,200.00**
Dogfish	450.00	-	-	-	-	-	450.00
Pacific cod	**1,200.00**	**-**	**-**	**-**	**-**	**-**	**1,200.00**
Lingcod	**705.13**	**176.28**	**80.14**	**20.04**	**14.72**	**3.68**	**1,000.00**
Canary rockfish	34.20	3.80	5.40	0.60	-	-	44.00
Pac. ocean perch	**-**	**150.00**	**-**	**-**	**-**	**-**	**150.00**
Darkblotch rockfish	**39.35**	**222.97**	**5.65**	**32.03**	**-**	**-**	**300.00**
Widow rockfish	**796.88**	**140.63**	**53.13**	**9.38**	**-**	**-**	**1,000.00**
Bocaccio	**-**	**-**	**108.00**	**12.00**	**-**	**-**	**120.00**
Yelloweye rockfish	9.00		4.00				13.00
Pacific whiting	115,401.25	115,401.25	6,073.75	6,073.75			242,950.00

Appendix B -- Analysis of spatial and temporal overlap of WCGF fisheries and protected cetacean species

Blake E. Feist[1], Marlene Bellman[2], Michael J. Ford[1], Mindi Sheer[1]and Phillip S. Levin[1]

[1]Conservation Biology Division, Northwest Fisheries Science Center
[2]Fishery Resource Analysis and Monitoring Division, Northwest Fisheries Science Center

December 23, 2011

Introduction

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 [1,2], vessel collisions [3], noise [4,5], exposure to toxins (hydrocarbons, exhaust, etc. [6,7]), entanglement with fishing gear [8] and marine debris [9], resource competition and habitat disturbance from fishing [10,11,12], and global climate change [13].

There is substantial evidence in the literature documenting direct mortality of various cetaceans from interactions with commercial and recreational fishing gear [8]. For example, sperm whales (*Physeter macrocephalus*), are especially susceptible to deepwater gillnets and bottom-set longline gear [14,15,16,17,18]. 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 [19]). 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.

In this analysis, we intersected spatially explicit predictions of cetacean density for 12 different species, with heretofore unavailable and spatiotemporally extant field surveyed fishing effort data from three major fishing fleets within the California Current Ecosystem. From this intersection we quantified the potential overlap for each cetacean species/fishing fleet combination. We found that there was tremendous variation in the exposure rates for the various cetacean species and this variation was a function of seasonality and fleet type.

Methods

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 cetacean density estimates, represented on a 23.6 - 26.8 km grid, that were generated by NOAA's Southwest Fisheries Science Center [20,21]. The models were generated using cetacean line-survey data collected from vessels that ran surveys from June through November in 1991, 1993, 1996, 2001 and 2005. They used Generalized Additive Models (GAMs) with nonparametric smoothing functions to predict cetacean densities from habitat variables. Habitat variables were a combination of in situ and remote sensed data, and included sea surface temperature (SST, remote sensed and in situ), sea surface salinity, surface chlorophyll and vertical properties of the water-column (in situ only). The grid covered most of the California Current Large Marine Ecosystem off the coast of Washington, Oregon and California. Twelve species of cetaceans were modeled by Barlow et al. ([21], Table CET1) and we used the predicted mean annual density (number of animals per km^2) for our analyses. For simplicity, these data are reported as "annual" means, even though they were collected during summer months of the year. Further, these geospatial datalayers do not purport to capture or represent intra-annual or seasonal variability in cetacean density, so they are reported as an "annual" mean. We used the composite mean annual density estimates (as opposed to the individual yearly estimates) based on data collected from 1991 – 2005 in order to represent general, overall patterns of cetacean distributions.

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 [22]. 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 [23] 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 CET2). 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 pole 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:

$$C = \sum_{s=1}^{5}\left(\frac{t_s}{T} \times \frac{w_{s(obs)}}{W_{s(land)}}\right)$$

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).

<u>Maps</u>

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.

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:

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

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.

Results

Commercial Fishing Effort

Overall, the spatiotemporal patterns of fishing fleet levels of 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 CET2). 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 by sector for all years combined.

Interannual patterns

Cumulative annual effort varied considerably over time for each of the fleets (Figure CET1). Fixed gear cumulative efforts had peaks in 2003 and 2005, with a downward trend from 2005 to 2009 (Figure CET1). Hake fleets gradually increased in cumulative effort level until 2008 and dropped down again in 2009 (Figure CET1). Trawl fleets had a drop in cumulative annual fishing effort in 2004, but returned to 2002 levels of effort by 2009 (Figure CET1).

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 CET2). Fixed gear fleets had the greatest interannual and intraannual variability in their effort. They generally had peak efforts during the summer months (Figure CET2-A). However, there was usually a second peak of effort in the fall (Figure CET2-A). Effort was lowest during the months of January, February, November and December (Figure CET2-A). Hake fleets had the least interannual but the greatest intraannual variability in their effort. Hake fleets do 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 CET2-B). Trawl fleets had higher interannual but moderate intraannual variability in their effort. Trawl fleets generally have considerable and consistent effort year round, but tend to taper towards the end of the year (Figure CET2-C). In 2002, however, there was a strong peak of effort from October through November.

Spatiotemporal patterns

There was considerable inter-fishery variability in the spatial extent of cumulative effort (Figure CET3). For the period 2002-2009, various fixed gear efforts occurred from the US/Mexico border, north to the US/Canada border (Figure CET3). There were concentrations of effort off the coasts of Los Angeles, San Diego, Caspar, Eureka, and the northern half of the Oregon coast (Figure CET3). Hake fishing efforts occurred over a much smaller region, spanning Oregon and Washington State (Figure CET3). The hake fleet was not as patchy compared with the fixed gear fleets, but there were areas of increased effort (Figure CET3). However, given that the effort sampled by observers for the fixed gear fleet was not consistent across all of the reporting sectors, some of the patchiness in the apparent fixed gear effort may be due to patchiness of the observer spatial coverage itself. The trawl fleet efforts were not quite as widespread as the fixed gear fleets, occurring consistently from Point Conception, CA, north to the US/Canada border (Figure CET3). Like the hake fleets, effort was more consistent along the range of activity.

Interannual spatial variability was greatest and most patchy for the fixed gear fleets (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 were 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 CET4 to CET15). 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. Not surprisingly, 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 spatial overlap with WCGF fisheries occurs with the fixed gear sector, with some local overlap index values exceeding 20 animal hours/km^2 near San Diego just north of Cape Mendocino (Figure CET4). Overlap with the trawl sector is much lower, with a few overlap indices exceeding ~4 animal hours/km^2 near Cape Mendocino and off of the San Francisco Bay (Figure CET4). Overlap with the hake sector was very limited, an was <0.5 animal hours/km^2 in all locations (Figure CET4).

Fin whale

The highest areas of spatial overlap with the fishery occur from the Columbia River mouth area northward, with overlap indices for the fixed gear sector of >20 animal hours/km^2 near the Columbia River mouth, and indices for the trawl sector >3 animal hours/km2 along the Washington Coast (Figures CET5). The highest overlap index with the hake sector was < 2 animal hours/km^2, off the northern Washington Coast (Figure CET5).

Baird's beaked whale

Fixed gear fishing fleets overlapped the most (Figure CET6) 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 CET6). For the trawl fleets, overlap was generally higher in the northern two thirds of the fleet operational area, with maxima occurring just west of Ozette Island, WA, and north of Cape Mendocino, CA (>0.65 animal hours/km^2, Figure CET6)

Short-beaked common dolphin

Short-beaked common dolphins overlapped the most with the fixed gear fleets from south of the Channel Islands down to the US/Mexico border (>1,076 animal hours/km^2, Figure ##). Overlap with the hake fleets 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 ##). Trawl fleets overlapped fairly consistently along the entire fishing domain, with maximum overlap occurring just west of Ozette Island, WA, just north of Cape Mendocino and off the coast of San Francisco (>83 animal hours/km^2, Figure CET7).

Risso's dolphin

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 south to the US/Mexico border (>129 animal hours/km^2, Figure CET8). Overlap with the hake fleet was greatest just west of Ozette Island, WA, and over the stretch from the mouth of the Columcia River south to the Stonewall Bank, OR, (>7 animal hours/km^2, Figure CET8). Maximal overlap with the trawl fleets occurred over farily large areas near Ozette Island, WA, and in a fairly large area of the Columbia River plume (>23 animal hours/km^2, Figure CET8).

Pacific white-sided dolphin

Pacific white-sided dolphin overlap with the fixed gear fishing fleets occurred near the mouth of the Columbia River, the Stonewall Bank, OR, and near Trinidad Canyon, CA (>289 animal hours/km^2, Figure CET9). Overlap with the hake and trawl fleets was most pronounced near Neah Bay, WA (>28 and >128 animal hours/km^2, respectively, Figure CET9).

Northern right whale dolphin

Maximum overlap between northern right whale dolphin and the fixed gear fleets occurred near the mouth of the Columbia River and Trinidad Canyon, OR (>115 animal hours/km^2, Figure CET10). The hake fleets overlapped the most near Neah Bay, WA (>9 animal hours/km^2, Figure CET10), 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 CET10).

Humpback whale

For the fixed gear portion of the fishery, peak areas of overlap (>17 animals hours/km^2) occur north of Cape Mendocina, off the central Oregon coast, and off the Columbia River mouth (Figure CET11). For the trawl fishery, the highest overlap indices occur along the north portion of the coast from Cape Mendocina to Cape Flattery, with areas of overlap > 3 animals hours/km2 (Figure CET11). The highest overlap indices for the hake fishery occur near Cape Flattery, and are < 2 animal hours/km2 (Figure CET11)

Dall's porpoise

Overlap with the fixed gear fishery 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 CET12). Maximum overlap with the hake fleets was near Neah Bay, WA, and in the region from the Columbia River plume south to around Heceta Valley (>40 animal hours/km^2, Figure CET12). The trawl fleets overlapped pretty consistently from Neah Bay, WA, all the way south to Cape Mendocino (>124 animal hours/km^2, Figure CET12).

Sperm whale

Overlap indices between the sperm whale distribution and the fishery are generally lower than for other whales. For the fixed gear sector, the maximum values are < 6 animal hours/km^2, and occur in only a few places north of Cape Mendocino (Figure CET13). Overlap indices for the trawl sector are fairly low and uniform from San Francisco to Cape Flattery, and generally < 1 animal hours/km^2 (Figure CET13). Overlap indices for the hake sector are all < 0.3 animal hours/km^2 (Figure CET13).

Striped dolphin

Striped dolphin overlapped most with the fixed gear fleets 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 CET14). In contrast, overlap with the hake fleets 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 CET14). Overlap with the trawl fleets was also fairly homogeneous, and was consistently high from the 45th parallel south to Santa Lucia Bank (>0.7 animal hours/km^2, Figure CET14)

<u>Small beaked whales</u>

Maximum fixed gear fleet overlap with small beaked whales occurred in the Columbia River plume, Stonewall Bank, OR, and the Trinidad Canyon, Vizcaino Knoll, and off the San Diego coast, CA (>11 animal hours/km^2, Figure CET15). 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 CET15). 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 CET15).

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 CET16, top panel). In general, the proportion of populations exposed to fixed gear fleets was highest, but not always (Short-beaked common dolphin, Pacific white-sided dolphin and northen right whale dolphin, Figure CET16, top panel). Short-beaked common dolphin, Pacific white-sided dolphin, northen right whale dolphin and humpback whale had the greatest proportion of their populations overlapping with commercial fishing activity. It's important to note that the proportions displayed by the bars in Figure CET16 (top panel) cannot be summed, as there was overlap between the different fleet types. Overlap with fixed gear fleets was greatest for blue whale, Pacific white-sided dolphin, humpback whale, and Pda, while maximum population overlap with hake fleets occurred in Pacific white-sided dolphin, humpback whale, and Dall's porpoise, and trawl fleets overlapped the most with Short-beaked common dolphin, Pacific white-sided dolphin, and humpback whale (Figure CET16, top panel).

Cumulative Overlap Index

<u>Overall patterns</u>

Overall, there were marked differences in the overlap indices of the different cetacean species (Figure CET16, bottom panel). The largest overlap indices occurred in the fixed gear fleet, which was 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 the fleet types and Baird's beaked and sperm whales, and striped dolphin had the lowest (Figure CET16, bottom panel). Within the three fleet types, 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 CET16, bottom panel).

Interannual patterns

As was the case with the overall cumulative overlap indices, there was considerable interspecific variation (Figure CET17). Overall, cumulative overlap indices (COI) were higher for the fixed gear fleets, compared with the hake and trawl fleets. For the 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 fleets, but dropped off markedly in 2009 (Figure CET17B). 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 CET17B). Finally, the trawl fleets COI were markedly different from the fixed and hake fleets. Aside from 2004, COI values were fairly consistent over time, or slightly declining (e.g., short-beaked common dolphin, Figure CET17C). The COI for all 12 cetacean species was significantly lower in 2004, with around 20 – 30% drops occurring in most species.

Discussion

Overall, it is clear that commercial fishing activities from the fixed, hake and trawl fleets operating in the California Current Large Marine Ecosystem overlap with the 12 cetaceans modeled in our analyses. There are pronounced inter- fleet and specific differences in overlap, and these overlap patterns are not consistent over time. For some species, the overlap rates have been increasing over time, whereas in others it is relatively stable.

Implications for cetaceans

It's important to note that while we quantified the relative level of exposure to the gear deployed by the three fishing fleets, we could not make conclusions about the actual impact this exposure might have on a given species. We know from the literature that cetacean interaction with commercial fishing gear occurs. We also know that some of these interactions cause harm or mortality. We cannot, however, infer or quantify the level of harm or mortality from our analyses. Rather, our results suggest that certain cetacean species have significantly more exposure to the gear deployed by commercial fishing fleets.

There are numerous sublethal or stress inducing mechanisms through which exposure to commercial fishing activities could alter cetacean ecology, including: vessel collisions, physical disturbance, acoustic disturbance, entanglement in nets or lines, pollution from exhaust or spills, and direct or indirect reduction of prey. These can all be considered "sensitivities" in a formal risk assessment, but were not quantified for our analyses. Quantifying said impacts would be difficult for many of the species, as the information on a given commercial fishing influence is often anecdotal or poorly understood. However, it is appropriate in the context of this discussion to provide a brief overview of the aforementioned stressors to provide insights into the inter- specific and fleet type variability.

Vessel collisions are less common with actively fishing vessels since their velocities decrease while gear is actively deployed. However, collisions are more likely when vessels are transiting between various fishing sites or ports. Overall, however, it appears as though collusions are one of the least harmful consequences of cetacean/fishing fleet interactions.

Large expanses of surface, pelagic and benthic habitats are actively fished commercially, in some cases year round, and this most certainly has an impact on habitat where cetaceans co-occur. Bottom trawl activity has been shown to dramatically alter the physical structure of benthic habitats, whereas surface and midwater trawls present significant physical disturbance to the waters where they are deployed.

There is considerable evidence that changes in marine ambient noise patterns have consequences for cetaceans. Cetaceans are obviously highly dependent on their active and passive auditory systems for prey and predator detection, communication, and navigation. Noise from commercial fishing vessels alters and increases the magnitude of ambient noise that cetaceans are exposed to.

Entanglement with the various fishing gear types can often be fatal for many cetaceans, but may also leave animals in a compromised condition where feeding, mating and/or predator avoidance abilities are diminished. Entanglement also varies tremendously by species and gear type (see other sections in risk assessment for detailed information).

Direct or indirect resource competition imposed by commercial fishing fleets is a real concern for many cetaceans. With the increase in ecosystem and entire food web based modeling efforts as of late, it is clear that commercial fishing operations than have impacts that propagate through food webs in both directions (i.e., top down, vs. bottom up). Even if a given fishing fleet is not targeting the same prey item as a given cetacean species, the consequences of a trophic cascade induced by fishing activity is a significant problem.

Given the variety of disturbance types associated with commercial fishing activity, cetaceans may avoid, be attracted to, or pay no attention to a given vessel. Avoidance may be due to noise, general disturbance or past experience. Attraction frequently occurs in those species that depredate fishing gear while it is in the water, which may increase the likelihood of entanglement.

Future spatiotemporal shifts in fishing fleet effort

For the years we analyzed in our analyses, the fishing fleets were operating under the traditional open access system, where any given vessel was permitted to catch as many fish up until a quota was reached for a given fishery in a given year. Under the newly adopted catch share program, a given vessel is given a quota, and if this quota is exceeded, the fisher must pay a severe penalty. This shift in fisheries management approach may affect the three fleets considered in these analyses in different ways. Fishers might switch over to a different type (such as fixed gear) in order to maximize the economic benefit of their catch share quota. Intensity of effort is likely to shift over time and space. For example, under the open access system, a given fisher would fish for a target species intensively until the entire fishery quota was met or an open fishing time period ended. This could mean changes in the future in the amount of time that gear is deployed. Under the catch share program, a given fisher may not deploy their gear for as long, so the apparent local effort from a given fisher might be lower.

There is only one example of gear switching that has occurred in other fishers that have implemented a catch share or ITQ program [24]. Gear switching is allowed within the WCGF but it remains to be seen if switching will occur in response to the new catch shares [25].

Limitations

We did not consider drift- and gillnet fisheries, or halibut, sablefish and other fleets, which may pose a greater threat to cetacean species compared with bottom and mid-water trawlers, and fixed gear fisheries. There is evidence that gillnet fisheries pose a greater risk to some cetacean species compared with other gear types. There is also better data, which have been used to assess mortality rates in some species [26]. Given the higher observed rates of mortality associated with gillnet based fishing fleets, pingers have been attached to gillnet fishing gear in order to repel cetacean and pinniped species [19].

We assumed a given fishing fleet and cetacean species were randomly distributed in any given gridcell, so did not account for cetaceans avoiding (i.e., noise, general disturbance) or being attracted to (depredation by cetaceans in longline and gillnet fisheries) commercial fishing activities. The former would reduce the apparent influence of commercial fishing activity whereas the latter would increase the potential effect.

This was not a formal risk assessment where you calculate a change in population growth 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 [27]. However, we argue that our analyses directly address 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.

Further work on the sensitivity of these species to the stressors induced by commercial fishing activities is needed before a more formal risk assessment can be made.

References Cited

1. Fair PA, Becker PR (2000) Review of stress in marine mammals. Journal of Aquatic Ecosystem Stress and Recovery 7: 335-354.
2. Curry BE (1999) Stress in mammals: The potential influence of fishery-induced stress on dolphins in the Eastern Tropical Pacific Ocean. La Jolla, CA USA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. NOAA-TM-NMFS-SWFSC-260 NOAA-TM-NMFS-SWFSC-260. 132 p.
3. Panigada S, Pesante G, Zanardelli M, Capoulade F, Gannier A, et al. (2006) Mediterranean fin whales at risk from fatal ship strikes. Marine Pollution Bulletin 52: 1287-1298.
4. Romano TA, Keogh MJ, Kelly C, Feng P, Berk L, et al. (2004) Anthropogenic sound and marine mammal health: measures of the nervous and immune systems before and after intense sound exposure. Canadian Journal of Fisheries and Aquatic Sciences 61: 1124-1134.
5. Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals (2003) Ocean Noise and Marine Mammals. Washington, D.C.: National Academies Press. 220 p.
6. Jarman WM, Norstrom RJ, Muir DCG, Rosenberg B, Simon M, et al. (1996) Levels of Organochlorine Compounds, Including PCDDS and PCDFS, in the Blubber of Cetaceans from the West Coast of North America. Marine Pollution Bulletin 32: 426-436.
7. Marsili L, Caruso A, Fossi MC, Zanardelli M, Politi E, et al. (2001) Polycyclic aromatic hydrocarbons (PAHs) in subcutaneous biopsies of Mediterranean cetaceans. Chemosphere 44: 147-154.
8. Read AJ, Drinker P, Northridge S (2006) Bycatch of Marine Mammals in U.S. and Global Fisheries. Conservation Biology 20: 163-169.
9. Williams R, Ashe E, O'Hara PD (2011) Marine mammals and debris in coastal waters of British Columbia, Canada. Marine Pollution Bulletin 62: 1303-1316.
10. Dayton PK, Thrush SF, Agardy MT, Hofman RJ (1995) Environmental effects of marine fishing. Aquatic Conservation: Marine and Freshwater Ecosystems 5: 205-232.
11. Herr H, Fock HO, Siebert U (2009) Spatio-temporal associations between harbour porpoise Phocoena phocoena and specific fisheries in the German Bight. Biological Conservation 142: 2962-2972.
12. DeMaster DP, Fowler CW, Perry SL, Richlen MF (2001) Predation and Competition: The Impact of Fisheries on Marine-Mammal Populations over the Next One Hundred Years. Journal of Mammalogy 82: 641-651.
13. MacLeod CD (2009) Global climate change, range changes and potential implications for the conservation of marine cetaceans: a review and synthesis. Endangered Species Research 7: 125-136.
14. Di Natale A, Notarbartolo di Sciara G (1994) A review of the passive fishing nets and trap fisheries in the Mediterranean Sea and of the cetacean bycatch. In:

Perrin WF, Donovan GP, Barlow J, editors. Gillnets and cetaceans: Reports of the International Whaling Commission, Special Issue 15. pp. 189-202.
15. Haase B, Felix F (1994) A note on the incidental mortality of sperm whales (*Physeter macrocephalus*) in Ecuador. In: Perrin WF, Donovan GP, Barlow J, editors. Gillnets and cetaceans: Reports of the International Whaling Commission, Special Issue 15. pp. 481–483.
16. Félix F, Haase B, Davis JW, Chiluiza D, Amador P (1997) A note on recent strandings and bycatches of sperm whales (*Physeter macrocephalus*) and humpback whales (*Megaptera novaeangliae*) in Ecuador. In: Perrin WF, Donovan GP, Barlow J, editors. Gillnets and cetaceans: Reports of the International Whaling Commission, Special Issue 47. pp. 917–919.
17. Hill PS, Laake JL, Mitchell EAD (1999) Results of a pilot program to document interactions between sperm whales and longline vessels in Alaska waters. Seattle, WA: United States Department of Commerce. NMFS-AFSC-108 NMFS-AFSC-108. 42 p.
18. Straley J, O'Connell T, Mesnick S, Behnken L, Liddle J (2005) Sperm Whale and Longline Fisheries Interactions in the Gulf of Alaska. North Pacific Research Board.
19. Barlow J, Cameron GA (2003) Field experiments show that acoustic pingers reduce marine mammal bycatch in the California drift gill net fishery. Marine Mammal Science 19: 265-283.
20. Barlow J, Ferguson MC, Becker EA, Redfern JV, Forney KA, et al. (2009) Predictive Modeling of Cetacean Densities in the Eastern Pacific Ocean. La Jolla, CA USA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. NOAA-TM-NMFS-SWFSC-444 NOAA-TM-NMFS-SWFSC-444. 229 p.
21. Barlow J, Forney KA (2007) Abundance and population density of cetaceans in the California Current ecosystem. Fishery Bulletin 105: 509-526.
22. National Oceanic and Atmospheric Administration (NOAA) (2011) At-Sea Hake Observer Program, Observer Sampling Manual. Seattle, WA: Northwest Fisheries Science Center, Fishery Resource Analysis and Monitoring Division. 47 p.
23. National Oceanic and Atmospheric Administration (NOAA) (2010) West Coast Groundfish Observer Training Manual. Seattle, WA: Northwest Fisheries Science Center, West Coast Groundfish Observer Program. 665 p.
24. Boyd RO, Dewees CM (1992) Putting theory into practice: individual transferable quotas in New Zealand's fisheries. Society and Natural Resources 5: 179–198.
25. Pacific Fishery Management Council, National Marine Fisheries Service (2010) Groundfish Fishery Management Plan Amendment 20 (Trawl Rationalization). Portland, OR & Seattle, WA: The Pacific Fishery Management Council & The National Marine Fisheries Service. 53 p.
26. Carretta JV, Price T, Read R, Petersen D (2004) Estimates of Marine Mammal, Sea Turtle, and Seabird Mortality in the California Drift Gillnet Fishery for Swordfish and Thresher Shark, 1996-2002. Marine Fisheries Review 66.

27. Zacharias MA, Gregr EJ (2005) Sensitivity and Vulnerability in Marine Environments: an Approach to Identifying Vulnerable Marine Areas. Conservation Biology 19: 86-97.

Figure Legends

Figure CET1. 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 CET2. 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 CET3. 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 CET4. 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 CET5. 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 CET6. 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 CET7. 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 CET8. 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 CET9. 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 CET10. 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 CET11. 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 CET12. 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 CET13. 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 CET14. 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 CET15. 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 CET16. Modeled proportion (%) 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 CET17. 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 CET1. Twelve species of cetaceans represented in predicted cetacean density geospatial datalayer [20,21].

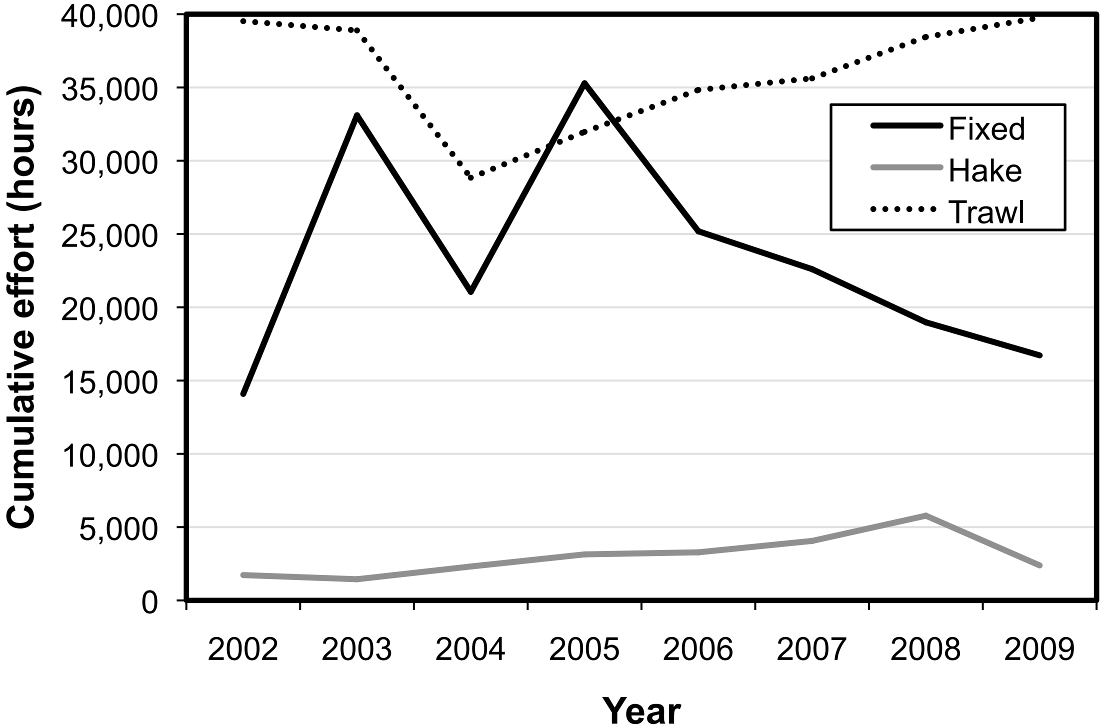
EN = endangered; LC = least concern; VU = vulnerable;

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

Table CET2. Fixed gear fishing effort represented in West Coast Groundfish Observer Program (WCGOP) data by sector observed, and the proportion of total effort (cumulative hours gear was deployed) represented by year.

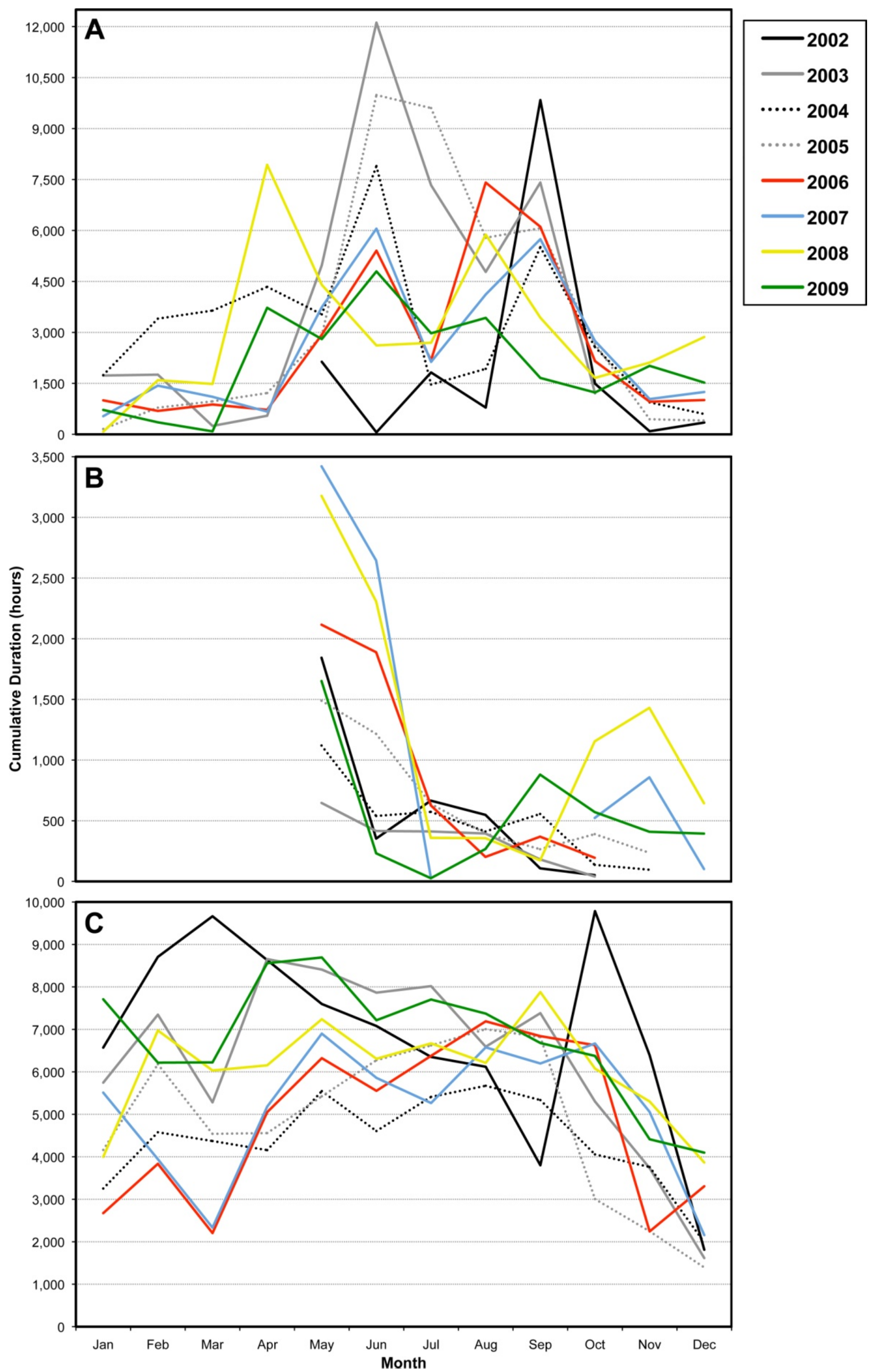
Sector (2002-2009)	% of Total Duration by Sector	Sector Coverage Rate	Proportion of Duration Represented
Limited Entry Sablefish Primary	59.38%	26.12%	15.51%
Limited Entry Non-Tier-Endorsed Fixed Gear	17.00%	7.41%	1.26%
Open Access Fixed Gear	18.63%	3.00%	0.56%
Oregon Nearshore Fixed Gear	3.83%	5.20%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

Sum total percentage of duration represented = 17.57%



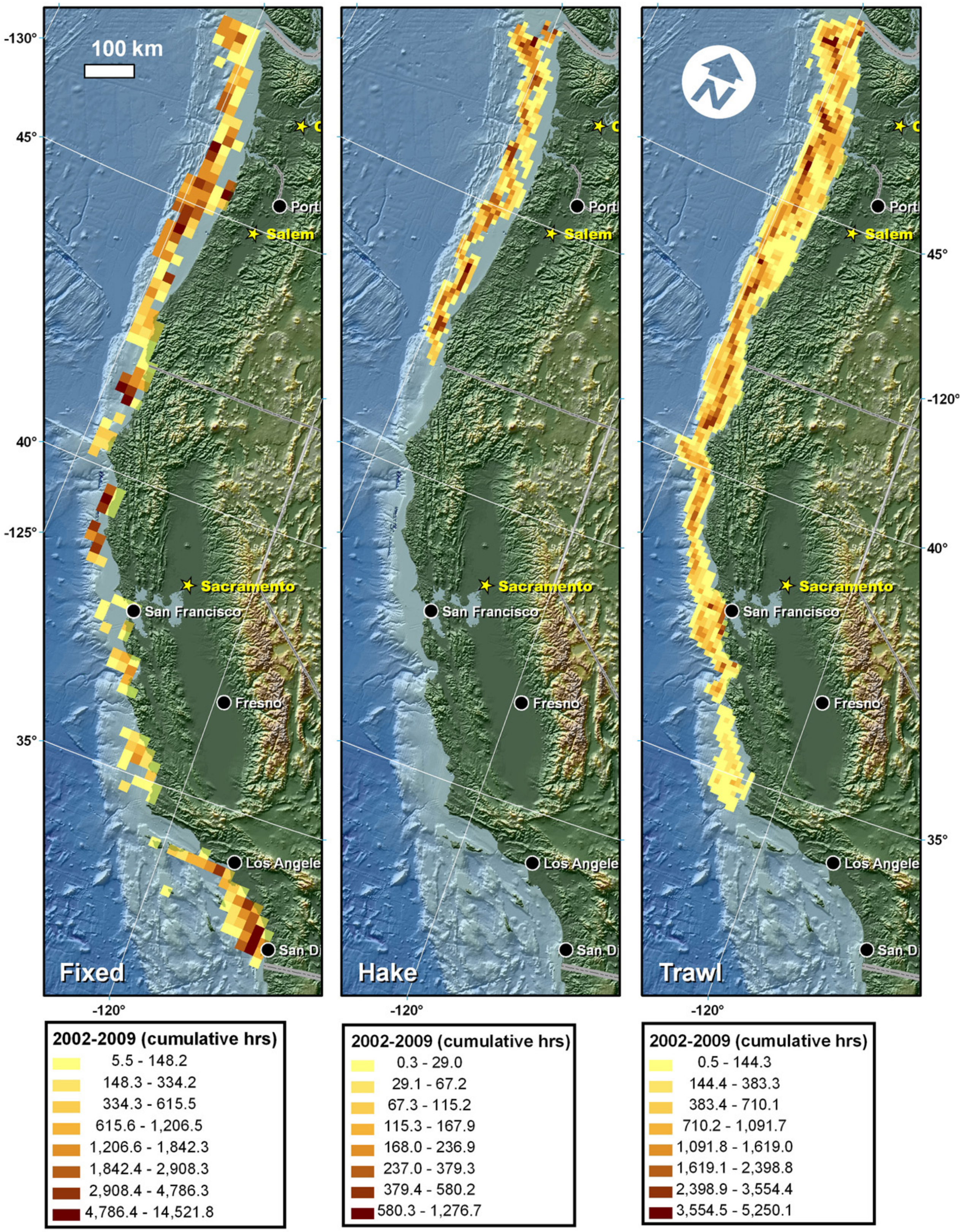
Cumulative effort (hours)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Fixed
Hake
Trawl
2002
2003
2004
2005
2006
2007
2008
2009
Year

Figure CET1



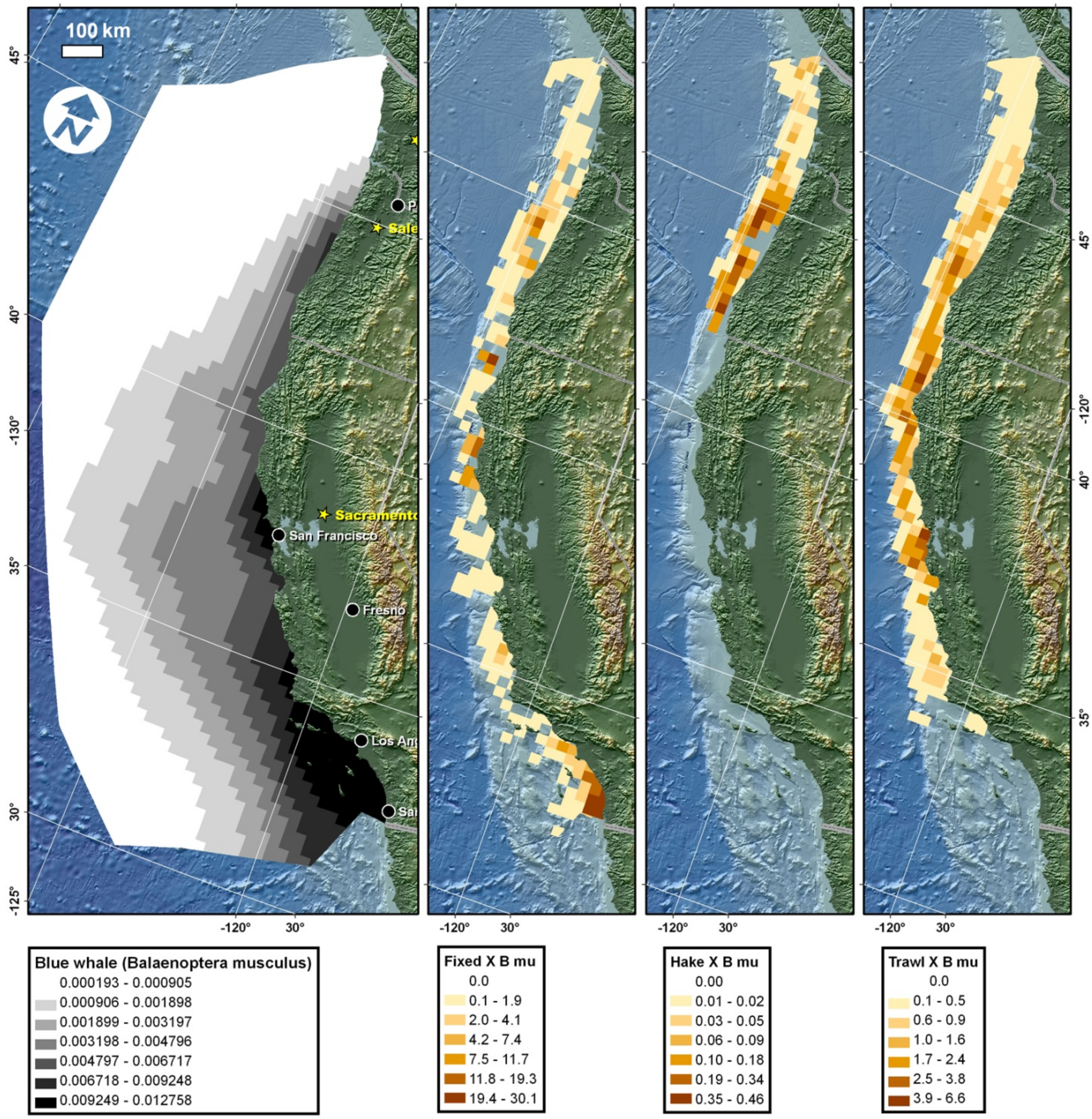
A
B
C
2002
2003
2004
2005
2006
2007
2008
2009
Cumulative Duration (hours)
Month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure CET2



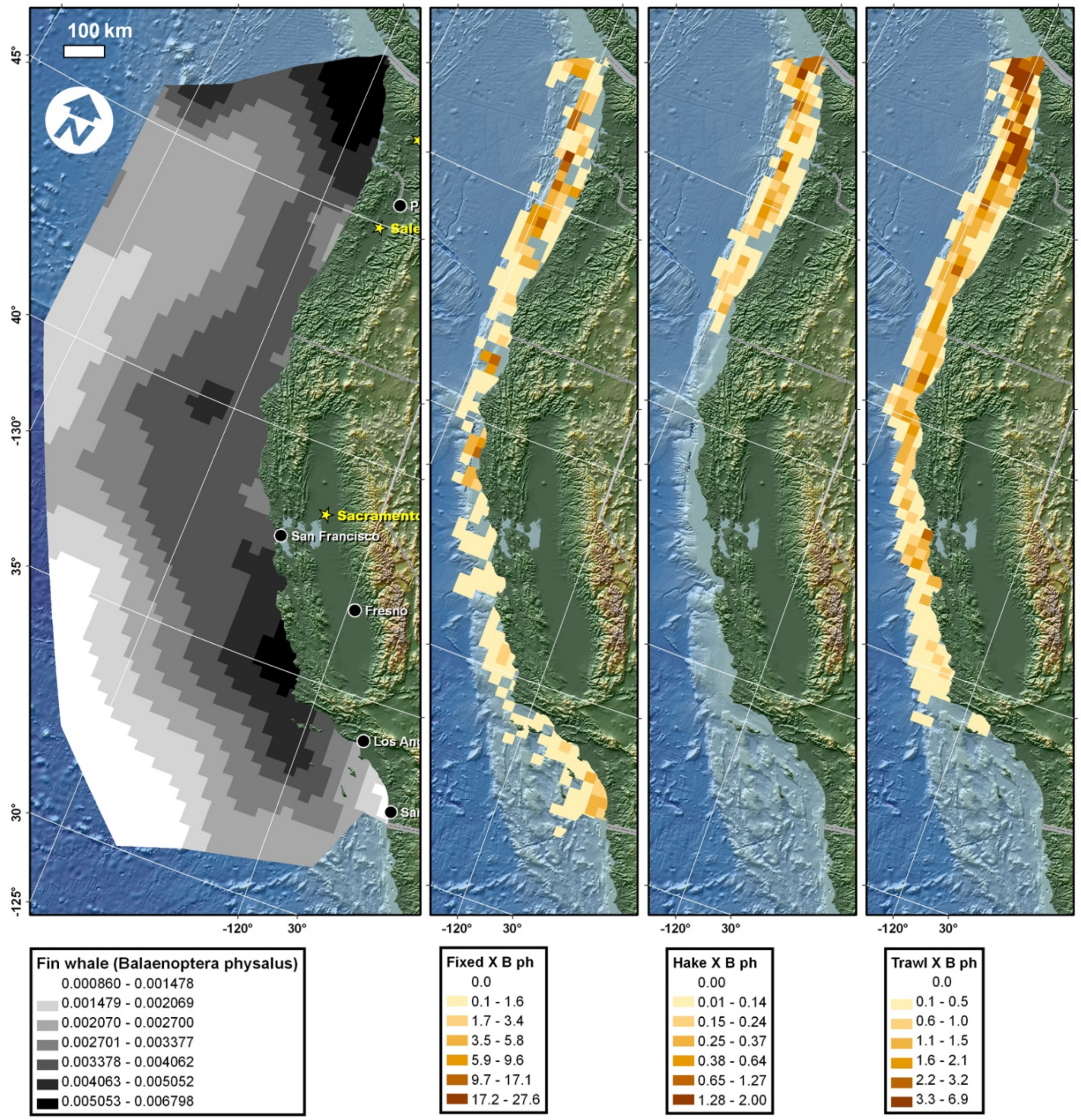
100 km
Fixed
Hake
Trawl
Salem
Sacramento
San Francisco
Fresno
Los Angele
San Di
Portl
-130°
45°
40°
-125°
35°
-120°
2002-2009 (cumulative hrs)
5.5 - 148.2
148.3 - 334.2
334.3 - 615.5
615.6 - 1,206.5
1,206.6 - 1,842.3
1,842.4 - 2,908.3
2,908.4 - 4,786.3
4,786.4 - 14,521.8
2002-2009 (cumulative hrs)
0.3 - 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 CET3



100 km
Sacramento
San Francisco
Fresno
Los An
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 CET4



100 km
45°
40°
-130°
35°
30°
-125°
-120°
30°
P
Sale
Sacramento
San Francisco
Fresno
Los An
Sa
45°
-120°
40°
35°
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 CET5

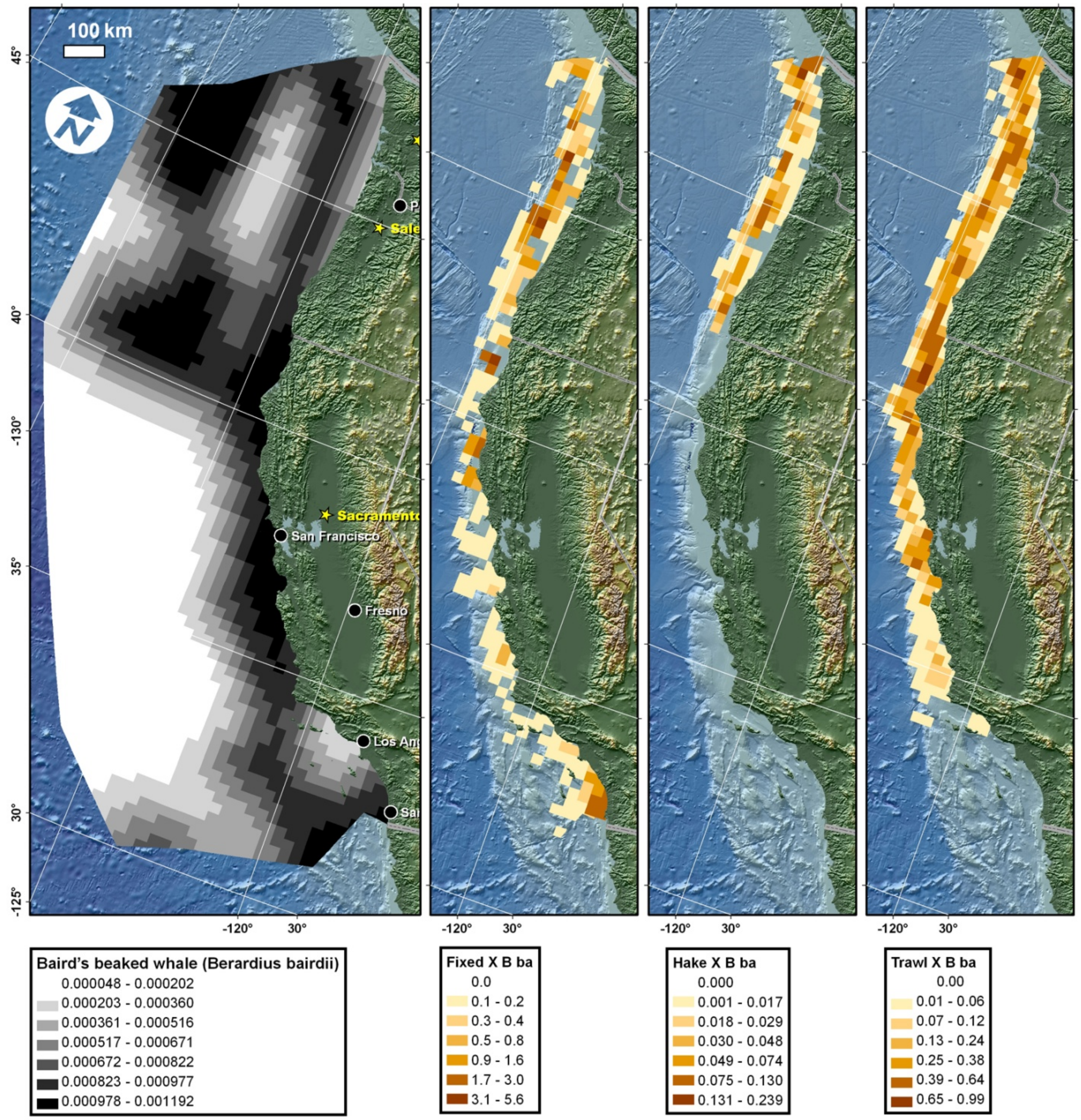
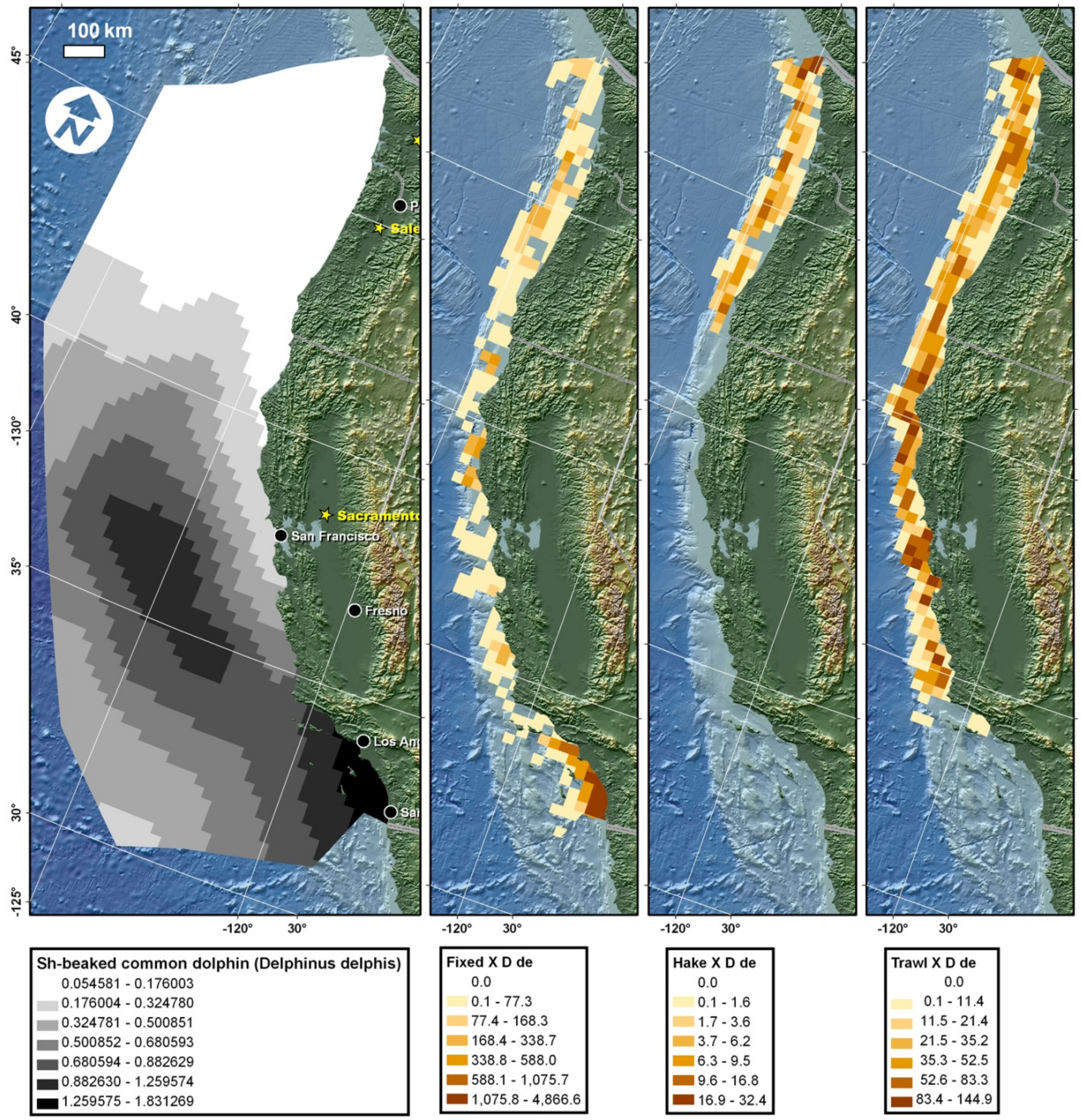

100 km
San Francisco
Sacramento
Fresno
45°
40°
-130°
35°
30°
-125°
-120°
30°
Baird's beaked whale (Berardius bairdii)
0.000048 - 0.000202
0.000203 - 0.000360
0.000361 - 0.000516
0.000517 - 0.000671
0.000672 - 0.000822
0.000823 - 0.000977
0.000978 - 0.001192
Fixed X B ba
0.0
0.1 - 0.2
0.3 - 0.4
0.5 - 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 CET6



100 km
San Francisco
Fresno
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 CET7

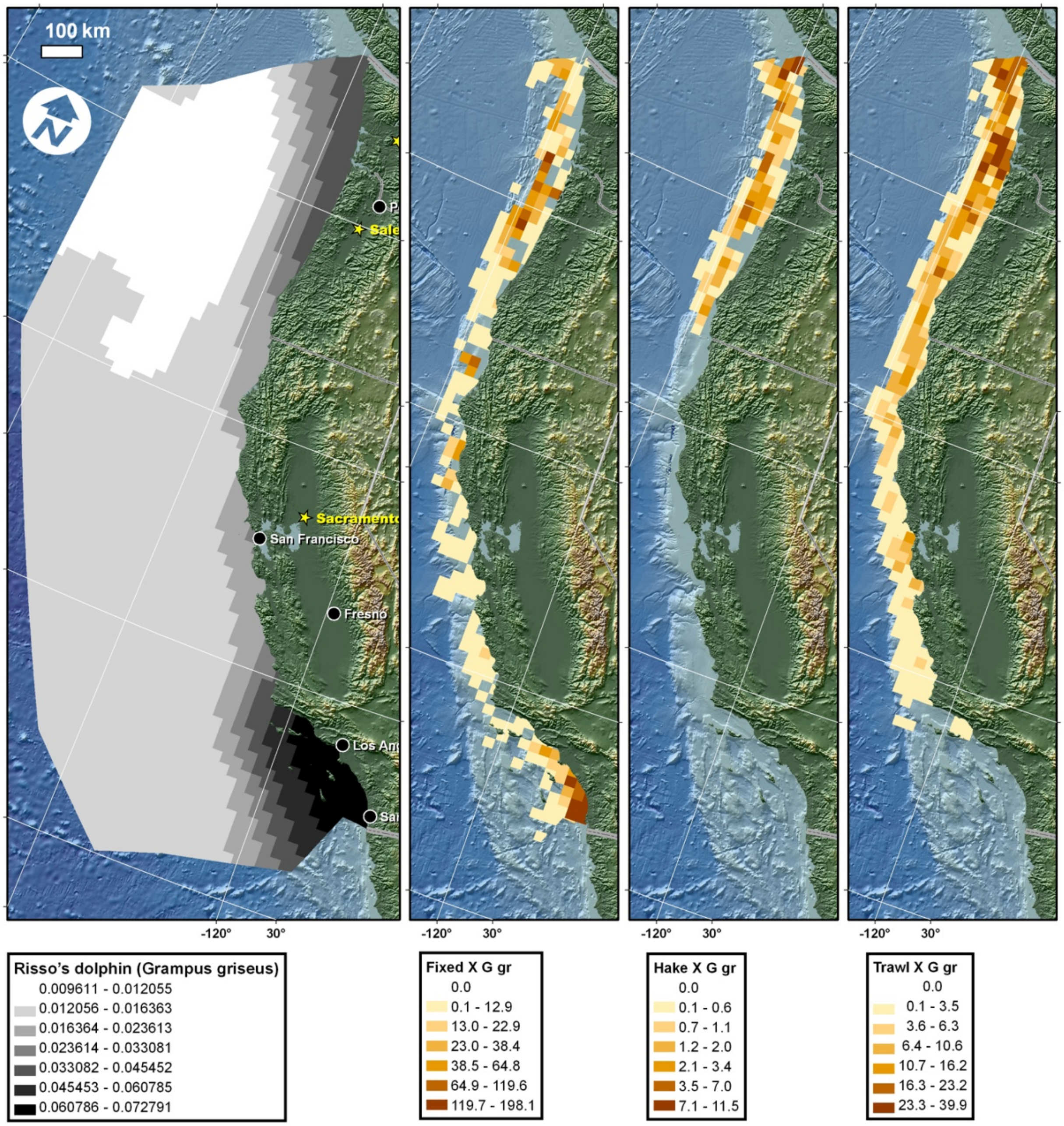
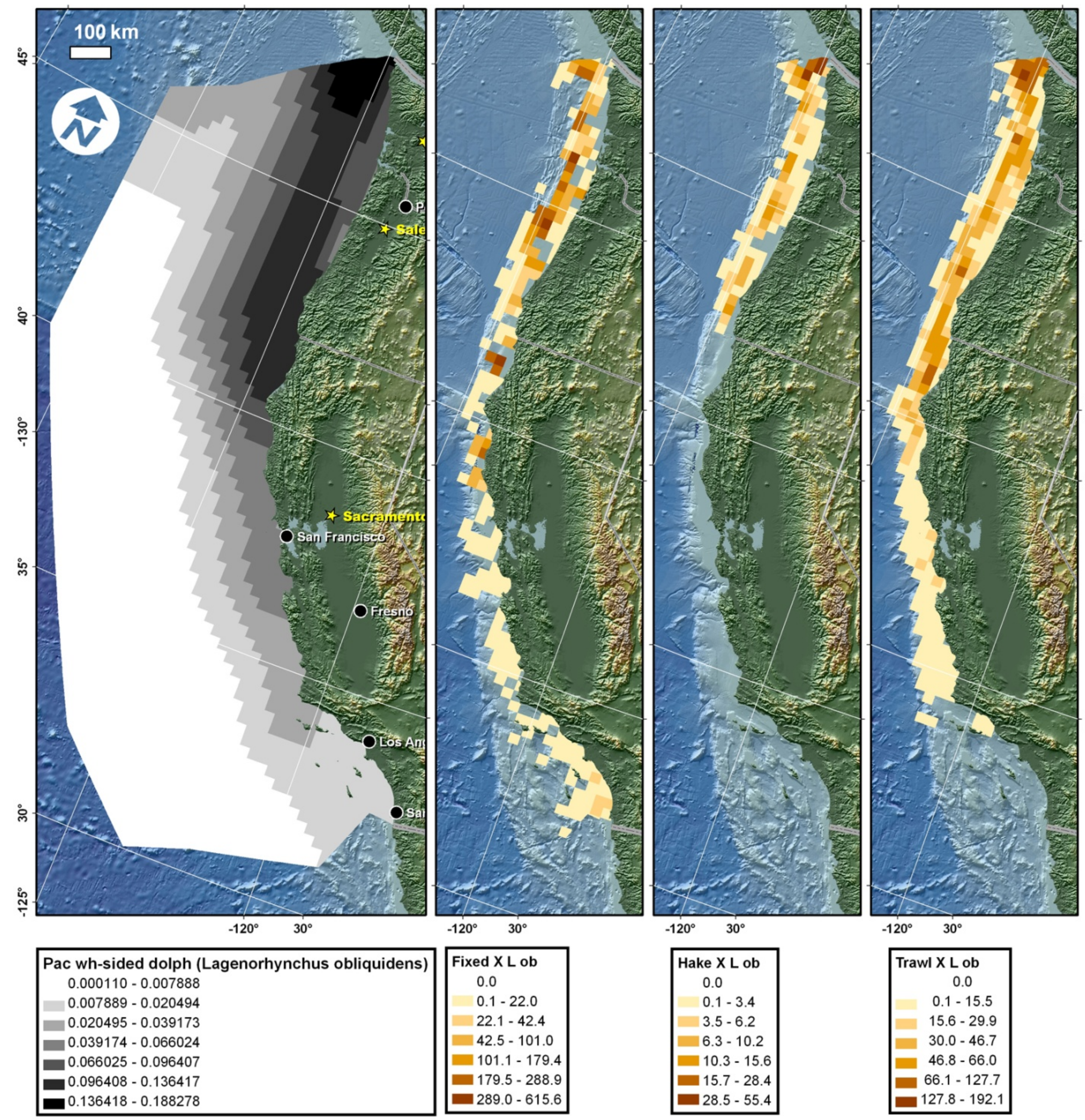

100 km
San Francisco
Fresno
Sacramento
Risso's dolphin (Grampus griseus)
0.009611 - 0.012055
0.012056 - 0.016363
0.016364 - 0.023613
0.023614 - 0.033081
0.033082 - 0.045452
0.045453 - 0.060785
0.060786 - 0.072791
Fixed X G gr
0.0
0.1 - 12.9
13.0 - 22.9
23.0 - 38.4
38.5 - 64.8
64.9 - 119.6
119.7 - 198.1
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 CET8



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 CET9

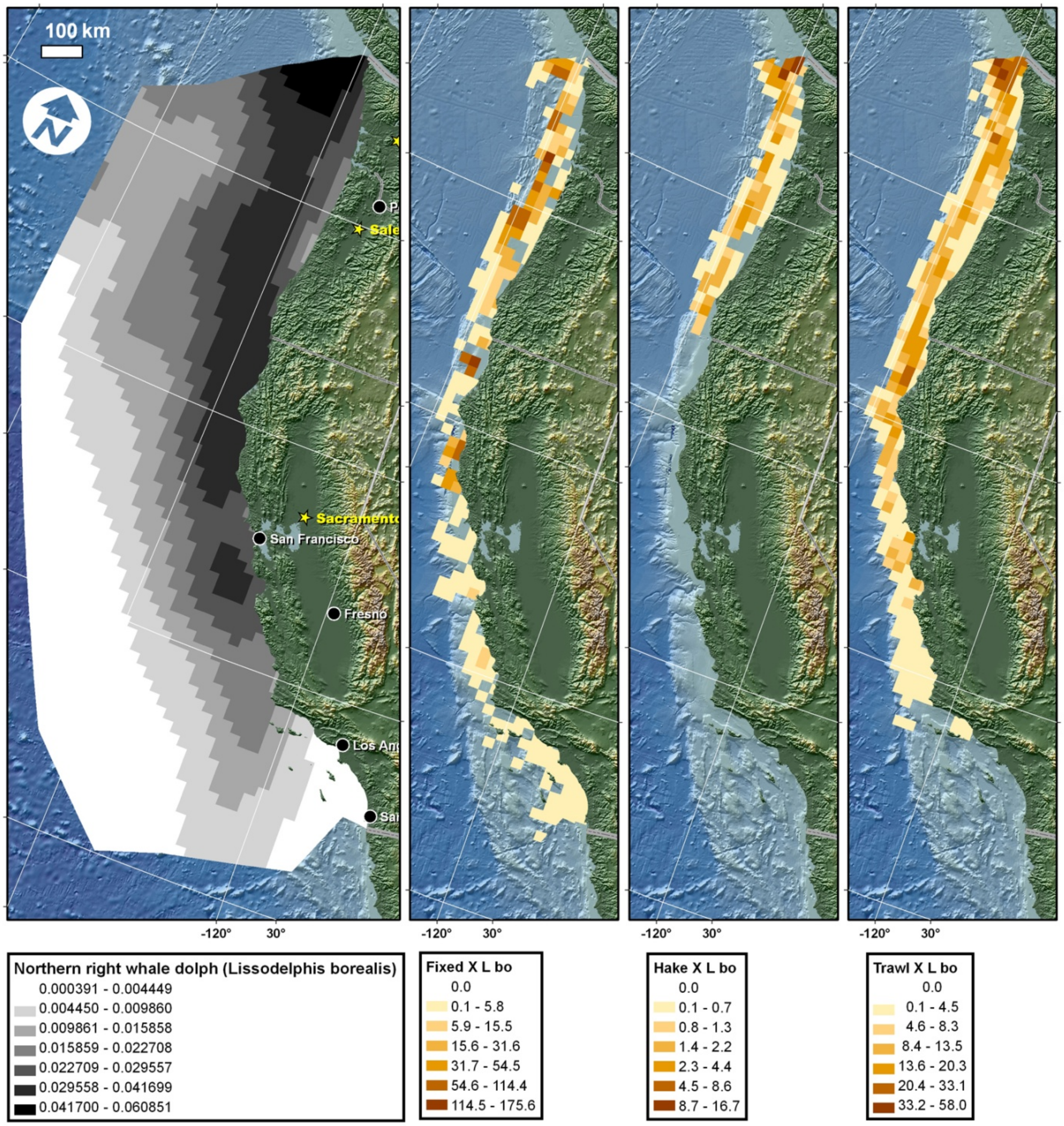


Figure CET10

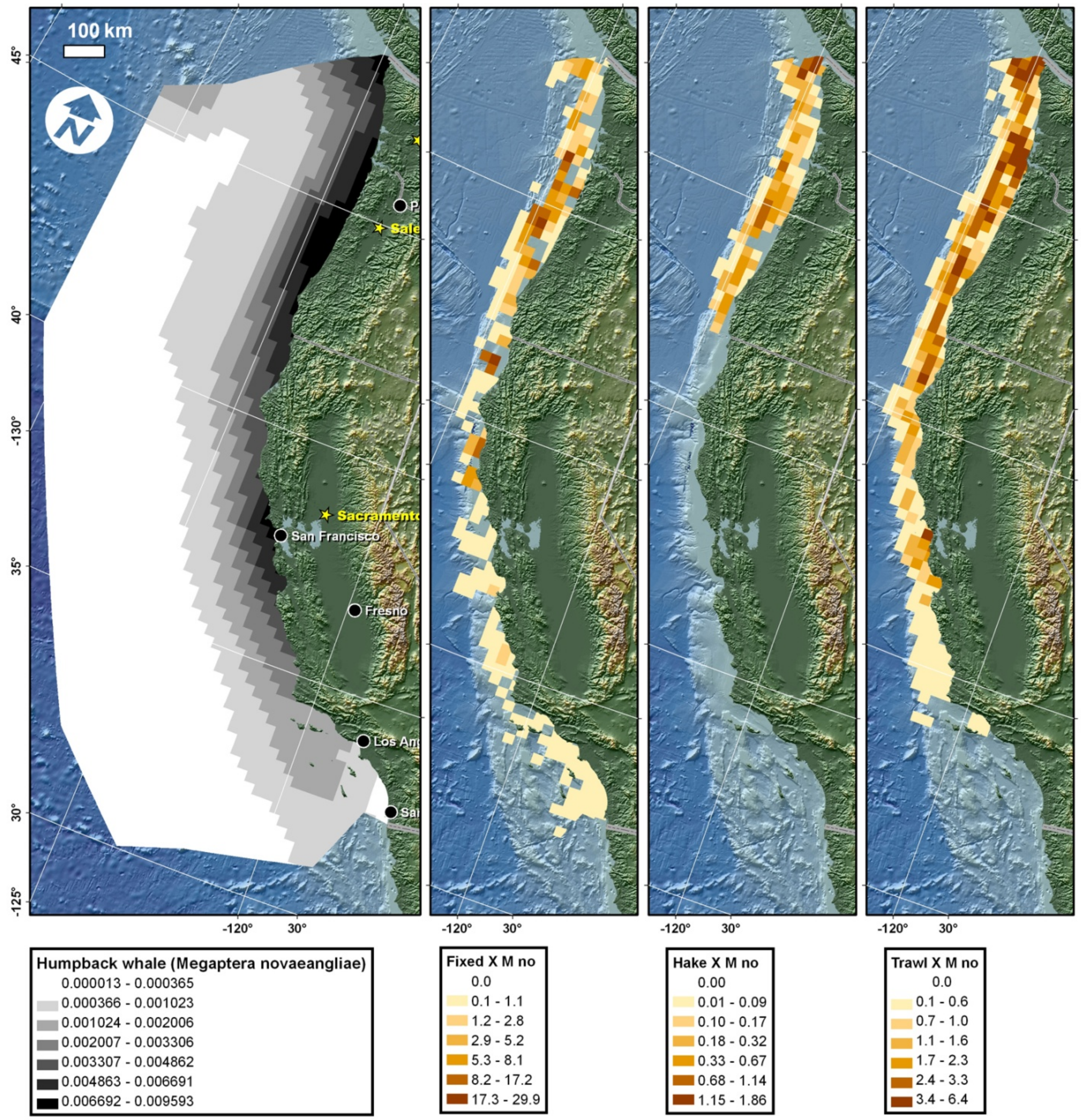


Figure CET11

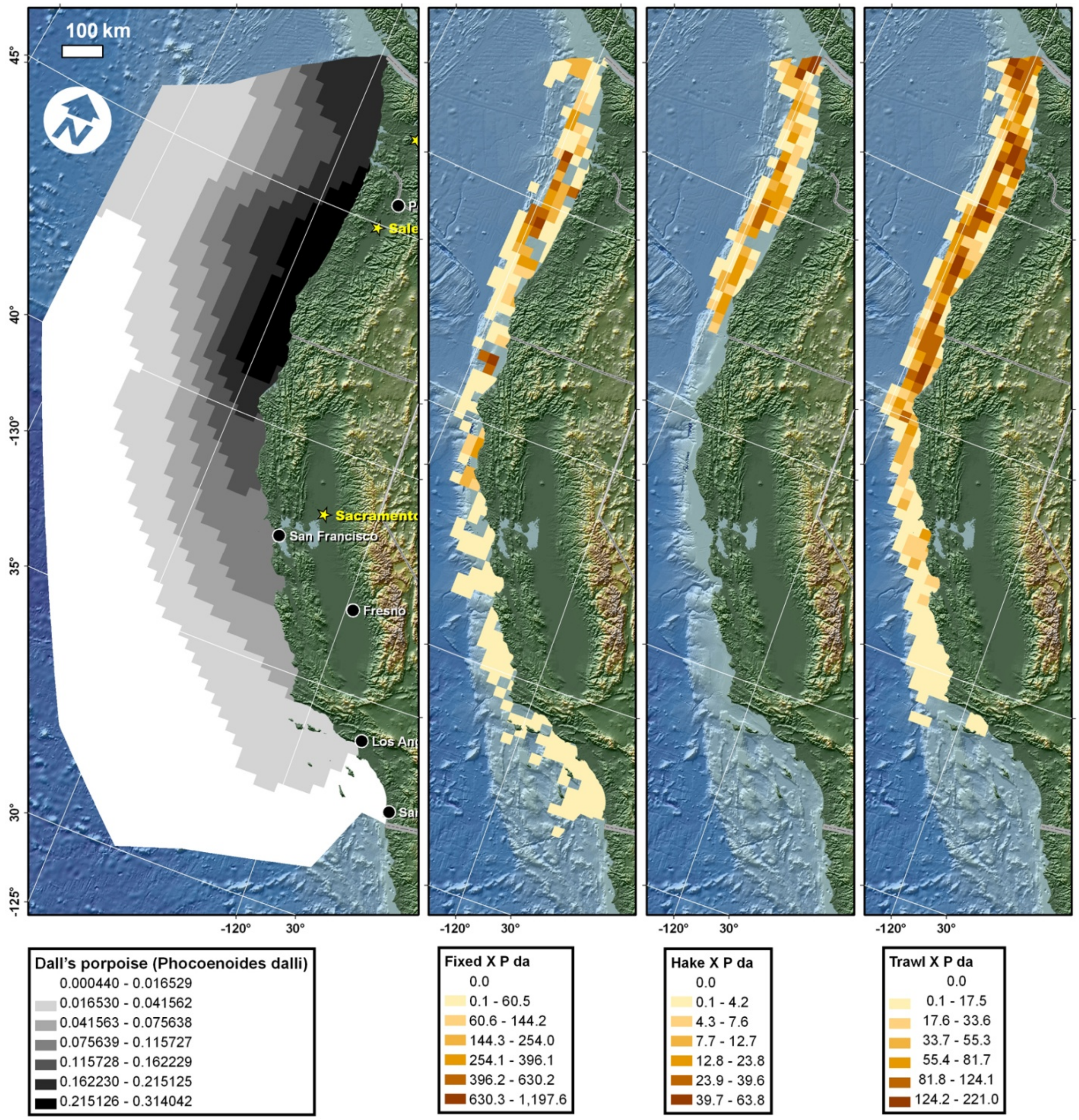


Figure CET12

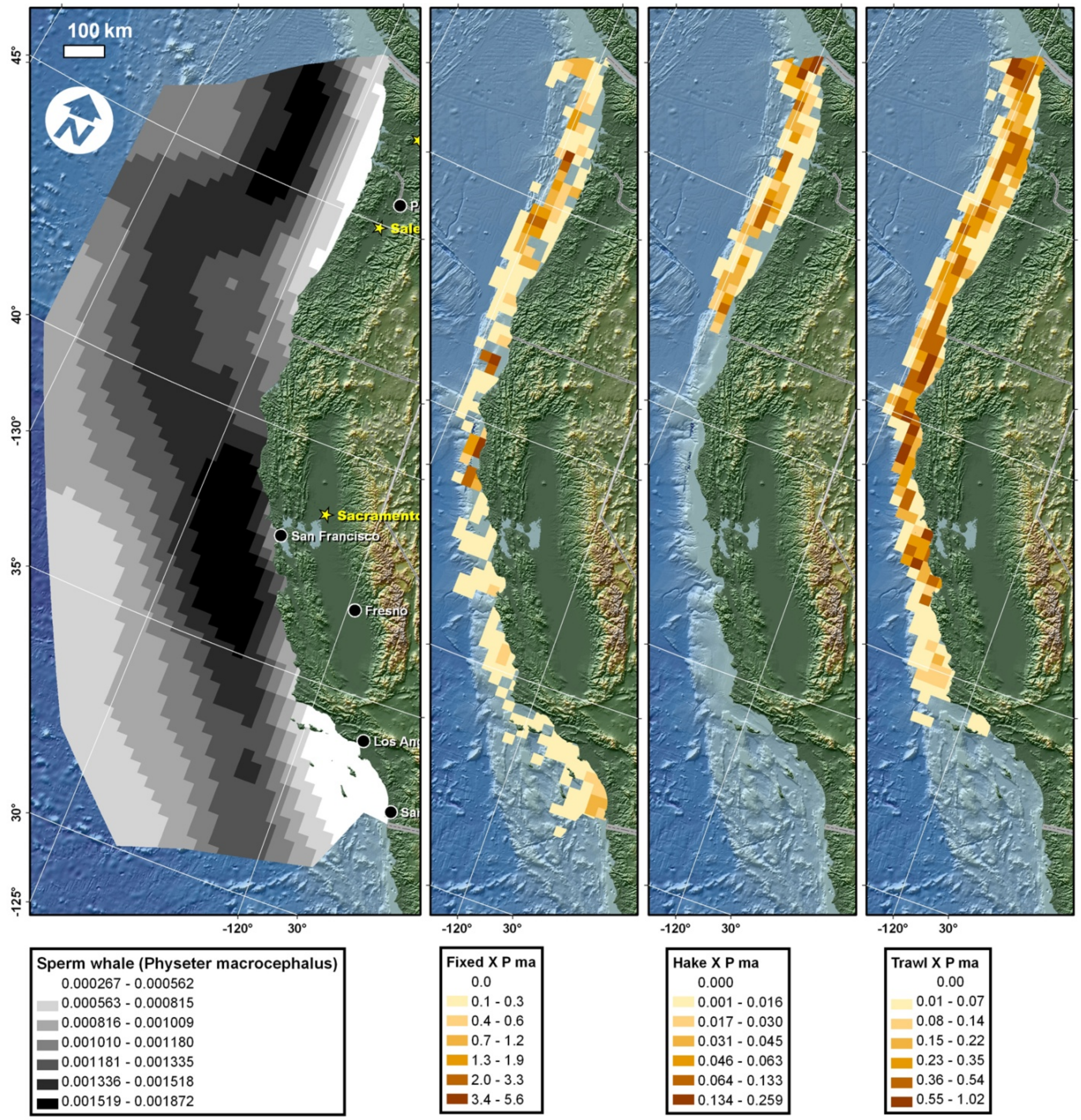


Figure CET13

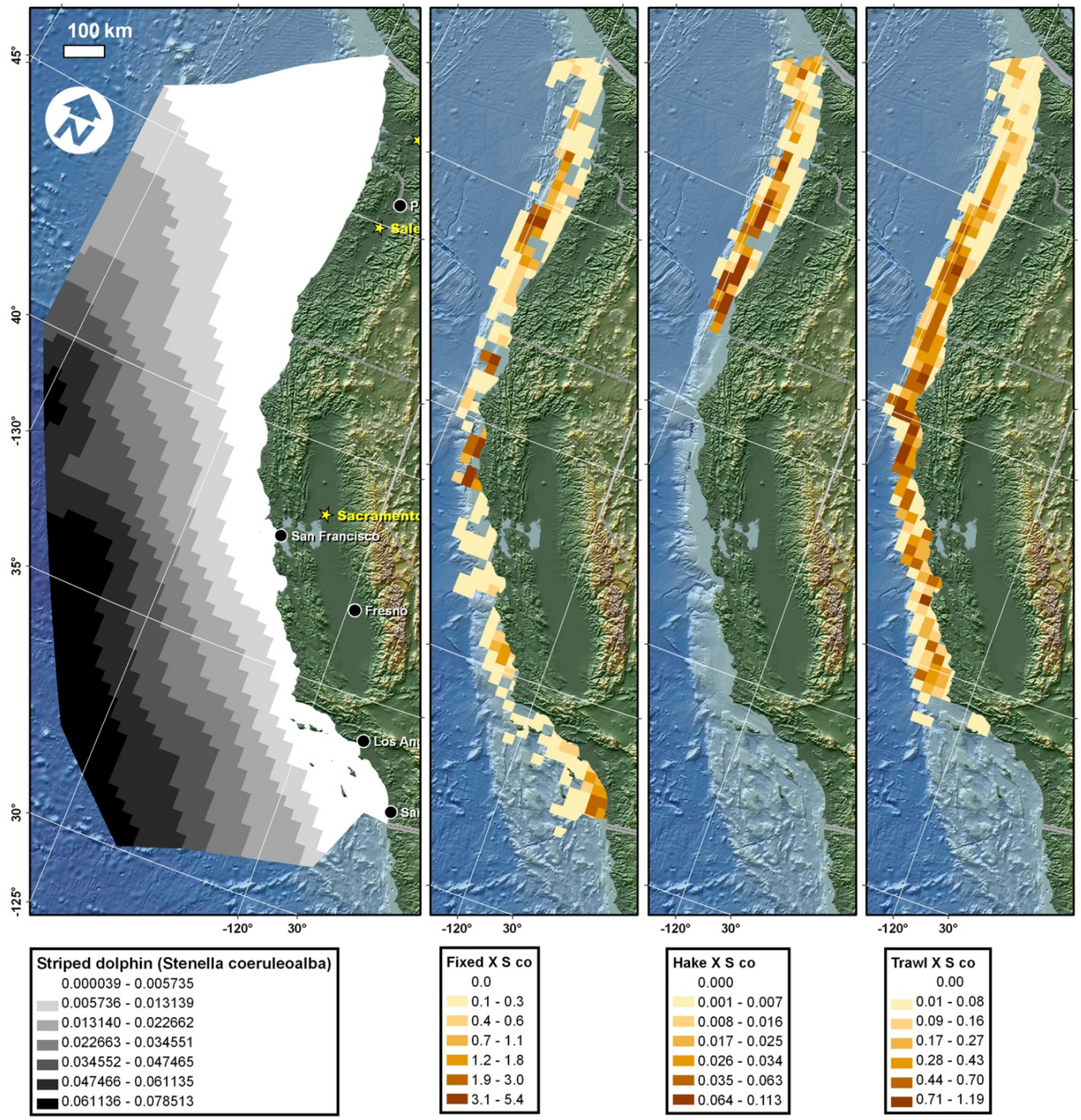


Figure CET14

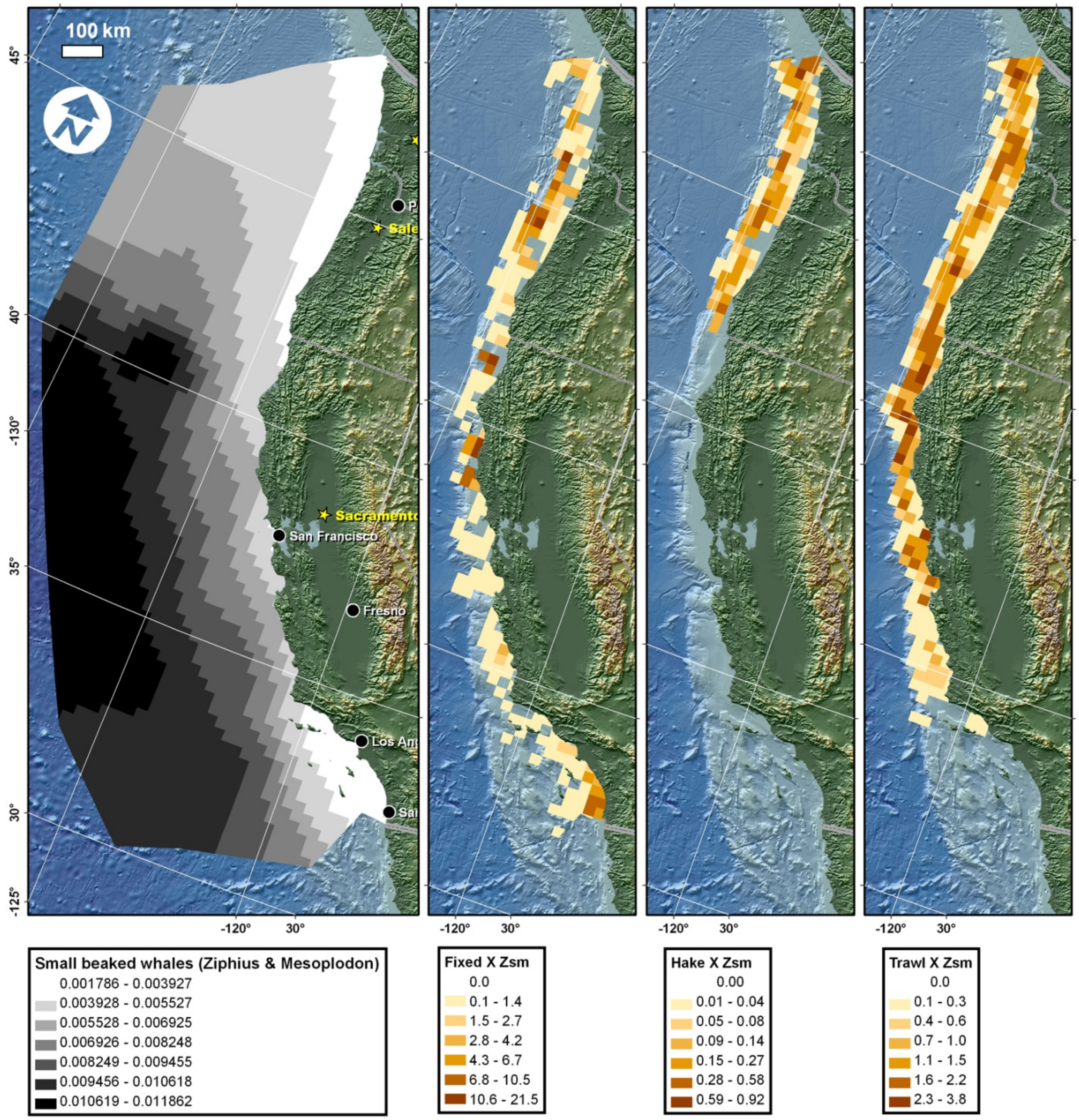


Figure CET15

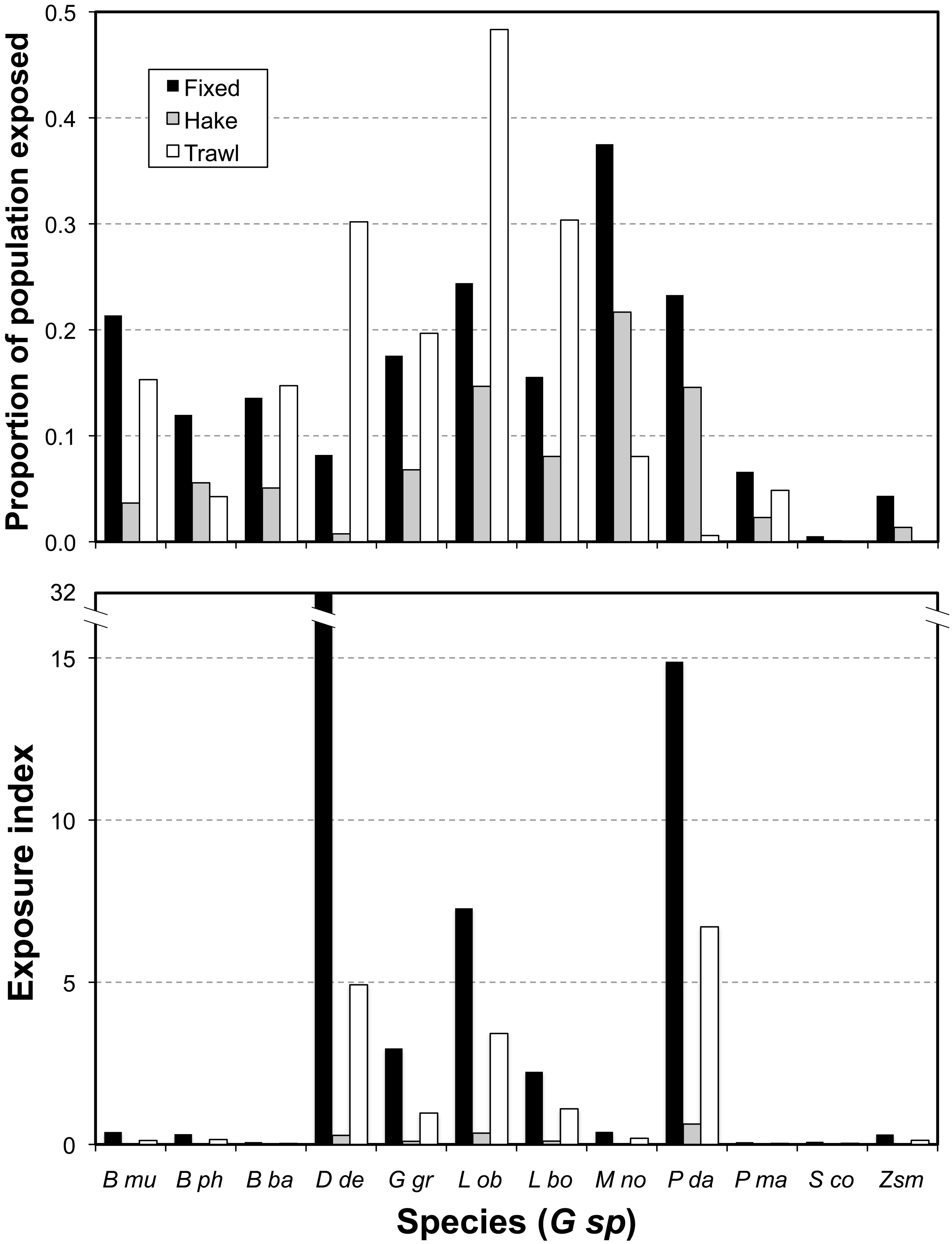


Figure CET16

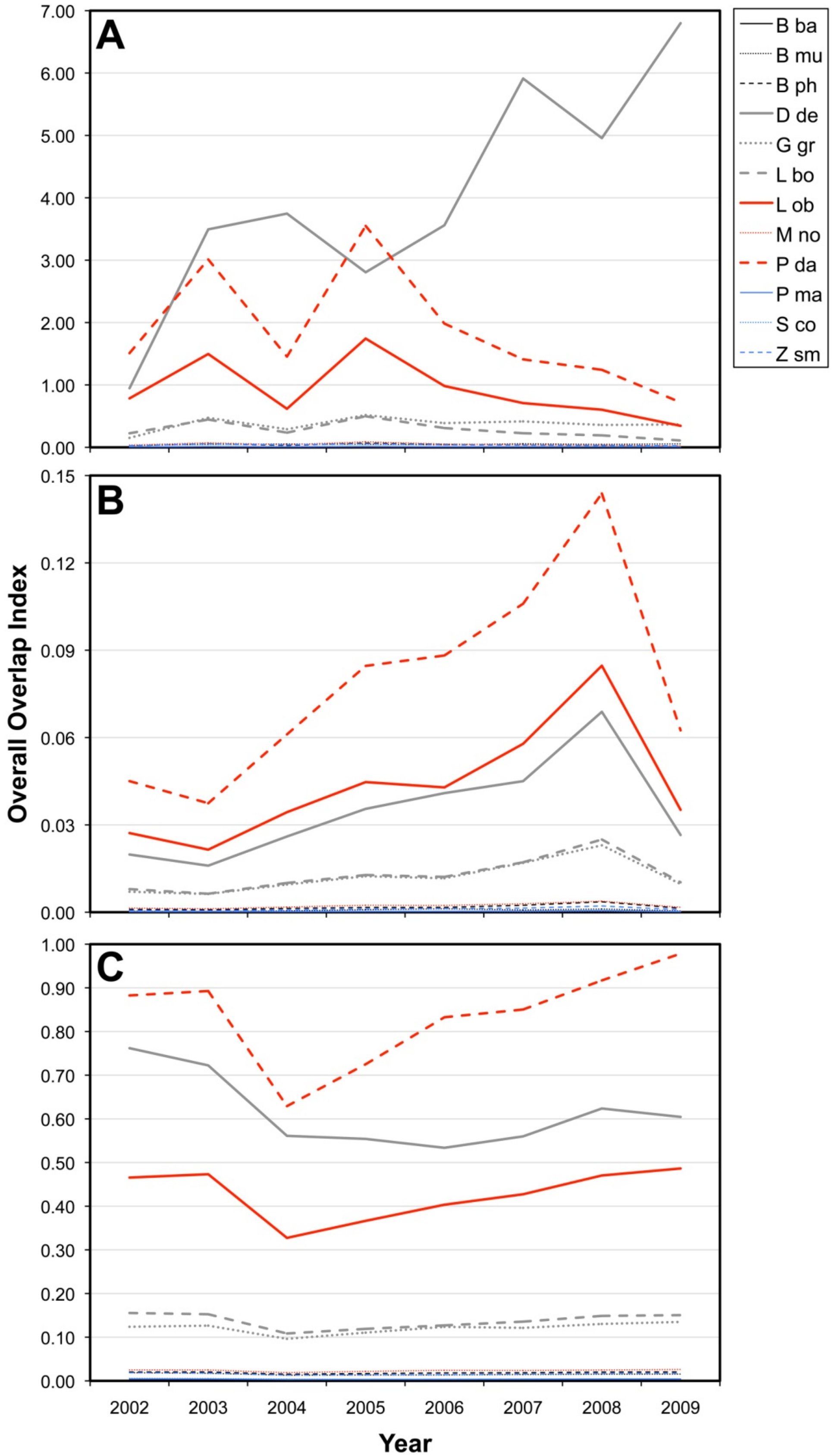


Figure CET17