

Draft Biological Report
for the
Proposed Designation of Critical Habitat for the Central America, Mexico, and
Western North Pacific Distinct Population Segments of Humpback Whales
(*Megaptera novaeangliae*)



Prepared by:
National Marine Fisheries Service
U.S. Department of Commerce
National Oceanic and Atmospheric Administration

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Cover photo: Humpback whale breaching in Prince William Sound, Alaska. Photo by John Moran, NOAA AFSC (under NMFS Permit 14122).

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Acronyms

BIA	Biologically Important Area
ESA	Endangered Species Act
CAM	Central America DPS
CCE	California Current Ecosystem
CHRT	Critical Habitat Review Team
CPS	Coastal Pelagic Species
DPS	Distinct Population Segment
EEZ	Exclusive Economic Zone
FMP	Fisheries Management Plan
MLLW	Mean Lower Low Water
MX	Mexico DPS
NMFS	National Marine Fisheries Service
NOS	National Ocean Service
NRC	National Research Council
PFMC	Pacific Fisheries Management Council
WNP	Western North Pacific DPS

Executive Summary

This report contains a synthesis and assessment of the best scientific data available to support a critical habitat determination under the Endangered Species Act (ESA) for three distinct population segments (DPSs) of humpback whales (*Megaptera novaeangliae*) – the Mexico, Central America, and Western North Pacific DPSs. These DPSs were listed under the ESA on September 8, 2016, when the National Marine Fisheries Service (NMFS) published a final rule revising the global listing of humpback whales (81 FR 62260). Once listed, the ESA requires that, to the maximum extent prudent and determinable, critical habitat be designated for endangered and threatened species based on the best scientific data available.

NMFS convened a critical habitat review team (CHRT) consisting of 10 biologists from NMFS and the National Ocean Service (NOS) to evaluate critical habitat for each of the three DPSs of humpback whales. CHRT members gathered, synthesized, and reviewed the best scientific data available to 1) determine the geographical area occupied by each DPS, 2) identify habitat features essential to the conservation of each DPS, 3) delineate specific areas within the geographical area occupied that contain at least one essential habitat feature that may require special management considerations or protection, and 4) assess the relative conservation value of all identified specific areas.

The geographical area occupied by the threatened Mexico DPS of humpback whales includes breeding areas off mainland Mexico and the Revillagigedo Islands; transiting areas off Baja California; and feeding areas in the North Pacific Ocean, primarily off California-Oregon, off northern Washington/southern British Columbia, in the Gulf of Alaska, and in the East Bering Sea (50 CFR 223.102(e)). The geographical area occupied by the endangered Central America DPS includes breeding areas off Central America (from Panama north to Guatemala, and possibly into southern Mexico) and feeding areas along the West Coast of the United States (California, Oregon, and Washington) and southern British Columbia (50 CFR 224.101(h)). Humpback whales of the endangered Western North Pacific DPS occupy breeding areas off Okinawa and the Philippines (as well as a poorly described breeding ground in the Western North Pacific Ocean), transiting areas around Ogasawara, and feeding areas in the North Pacific Ocean, primarily in the West Bering Sea and off the Russian coast and the Aleutian Islands (50 CFR 224.101(h)).

Because critical habitat cannot be designated in foreign countries or areas outside of U.S. jurisdiction, the CHRT limited its review to habitats occupied and used by the whales within U.S. waters, which primarily serve as feeding areas. Based on the CHRT's review of the best available scientific data, the CHRT unanimously concluded that prey within humpback whale feeding areas are essential to the conservation of each of the three DPSs of humpback whales. This essential feature was defined as follows:

Prey species, primarily euphausiids and small pelagic schooling fishes of sufficient quality, abundance, and accessibility within humpback whale feeding areas to support feeding and population growth.

The CHRT concluded that this essential feature may require special management considerations or protections as a result of ecosystem shifts driven by climate change, commercial fisheries, and pollution.

Within the geographic areas occupied, the CHRT identified nine specific areas encompassing 122,809 square nautical miles (nmi²) of marine habitat for the Western North Pacific DPS, nine specific areas encompassing 62,947 nmi² of marine habitat for the Central America DPS, and 19 specific areas encompassing 207,908 nmi² of marine habitat for the Mexico DPS - all of which contain the identified essential feature. The Western North Pacific and Central America DPSs do not have any specific areas in common; however, 12 of the 19 specific areas identified for the Mexico DPS are shared with one of the other DPSs (see Figure ES1). As a final step, the CHRT evaluated each of the specific areas to assess their relative conservation value for each humpback whale DPS. Results of that analysis (shown in Figure 19 and Table 3 of this report) may be used to inform a potential, subsequent analysis comparing the benefits of designating any particular area to the impacts of designating the particular area.

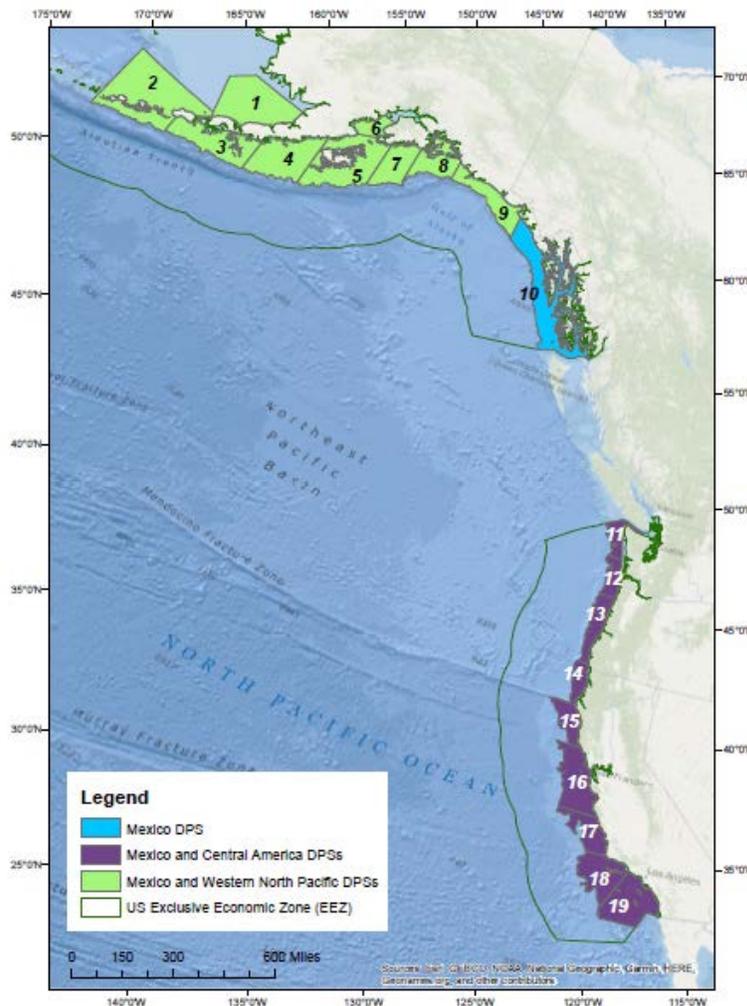


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Background

On September 8, 2016, the National Marine Fisheries Service (NMFS) published a final rule that revised the listing of humpback whales by removing the taxonomic species listing, listing four distinct population segments (DPSs) as endangered, and listing one DPS as threatened (81 FR 62260). NMFS also determined that nine additional DPSs did not warrant listing. Section 4(a)(3)(A) of the ESA requires that, to the maximum extent prudent and determinable, critical habitat is designated at the time of listing (16 U.S.C. 1533(a)(3)(A)). In the final rule to list the five DPSs of humpback whales, NMFS concluded that critical habitat was not yet determinable and thereby extended by one year the statutory deadline for designating critical habitat (16 U.S.C. 1533(b)(6)(C)(ii)).

Critical habitat cannot be designated within foreign countries or in areas outside the jurisdiction of the United States (50 CFR 424.12(g)). Three of the five DPSs of humpback whales have ranges that extend into U.S. waters – the Mexico, Central America, and Western North Pacific DPSs. Humpback whales from a population described as the Hawaii DPS also occur within U.S. waters and co-occur with listed humpback whales in portions of their range (Bettridge *et al.* 2015). However, because the Hawaii population of whales is not ESA-listed, critical habitat cannot be designated for these whales.

The Mexico DPS is listed as threatened and has been most recently estimated to have an abundance of 2,806 whales (CV= 0.055, Wade 2017). Entanglement in fishing gear, especially off the coasts of Washington, Oregon, and California, was identified as the primary threat to this DPS. Entanglement has been documented primarily in pot and trap gear but also in gillnets (Carretta *et al.* 2018). Other threats to this DPS include ship strikes and persistent organic pollutants, although, at the time of listing, these threats were not considered to be significantly impacting the survival of this DPS (Fleming and Jackson 2011, Bettridge *et al.* 2015). More recently, Rockwood *et al.* (2017) estimated that the mortality due to ship strikes (n=22 per year) is greater than the estimated fishery bycatch and is equal to the potential biological removal (PBR) level for the California/ Oregon/ Washington stock of humpback whales (Carretta *et al.* 2018). (PBR is defined under the Marine Mammal Protection Act (MMPA) as the maximum number of animals, not including natural mortalities, that may be removed from the stock while allowing that stock to reach or maintain its optimum sustainable population.) Whales within the Mexico DPS have a broad distribution within U.S. waters and occur along the coasts of Washington, Oregon, California, and Alaska.

The Central America DPS is listed as endangered and has been most recently estimated to include 783 whales (CV = 0.170, Wade 2017). Entanglement in fishing gear and vessel collisions, in particular, were identified as the most significant threats to this DPS. Within U.S. waters, whales of this DPS are most commonly observed off the coasts of California, Oregon, and Washington.

The Western North Pacific DPS is listed as endangered and has an estimated abundance of 1,066 whales (CV= 0.079, Wade 2017). There is a high degree of uncertainty regarding the threats to this DPS; however, entanglement in fishing gear likely represents a serious threat (Brownell *et al.* 2000, Baker *et al.* 2006). Other likely threats to this DPS include offshore energy development activities, vessel collisions, pollution, and food competition (with fisheries, Bettridge *et al.* 2015). Humpback whale meat

has been identified in Japanese and Korean markets, and it is possible that whaling could be posing a threat to this DPS (Brownell *et al.* 2000, Baker *et al.* 2006). Within U.S. waters, whales from this DPS have been observed in waters off Alaska, primarily near the eastern Aleutian Islands.

A critical habitat review team (CHRT) was convened to assess and evaluate information in support of a critical habitat designation for these three DPSs of humpback whales. The CHRT consisted of 9 biologists from NMFS and two from the National Ocean Service (NOS) with expertise and experience in humpback whale research or management, experience in developing critical habitat designations, or expertise in geographic information systems (GIS). To determine critical habitat for the DPSs, the CHRT (“we”) reviewed available data on humpback whales, including the global assessment of humpback whales and the status review that were completed in support of the ESA listings (Fleming and Jackson 2011, Bettridge *et al.* 2015), the proposed and final listing rules for humpback whales (76 FR 22304, April 21, 2015; 81 FR 62260, September 8, 2016), recent biological surveys and reports, and peer-reviewed literature. The CHRT also convened a workshop on May 22-23, 2018, at the NMFS Alaska Fisheries Science Center (AFSC) in Seattle, Washington that brought together CHRT members as well as 11 additional researchers from either the AFSC or other parts of NMFS. Several other individuals from external organizations (specifically, Cascadia Research Collective, Oregon State University, and Moss Landing Marine Laboratories) participated during parts of the workshop either in person or remotely to present and discuss their relevant research. This report summarizes the available data on habitat uses and needs of humpback whales and the CHRT’s process for determining what areas meet the definition of critical habitat. The report also provides the CHRT’s assessment of the relative value of the identified critical habitat units to the conservation of each individual DPS of humpback whales. The assessment and findings provided in this report, in conjunction with other agency analyses (e.g., economic analyses), will be used to inform and support NMFS’ proposal to designate critical habitat for the Mexico, Central America, and Western North Pacific DPSs of humpback whales.

Critical Habitat

The ESA defines critical habitat under section 3(5)(A) as:

- “(i) the specific areas within the geographical area occupied by the species at the time it is listed..., on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and
- (ii) specific areas outside the geographical area occupied by the species at the time it is listed... upon a determination by the Secretary that such areas are essential for the conservation of the species.”

Section 4(a)(3)(B)(i) of the ESA precludes from designations any lands owned by, controlled by, or designated for the use of the Department of Defense that are covered by an integrated natural resources management plan that the Secretary [of Commerce] has found in writing will benefit the listed species.

Section 4(b)(2) of the ESA requires NMFS to designate critical habitat for threatened and endangered species on the basis of the best scientific data available and after taking into consideration the economic impact, impact on national security, and any other relevant impact, of specifying any particular area as critical habitat. This section grants the Secretary discretion to exclude any particular area from critical habitat if “the benefits of such exclusion outweigh the benefits of specifying such area as part of the critical habitat.” The Secretary’s discretion is limited, however, by the statutory requirement that areas cannot be excluded if such exclusion will result in the extinction of the species.

Once critical habitat is designated, section 7 of the ESA requires federal agencies to ensure that actions they fund, authorize, or carry out will not destroy or adversely modify that habitat. This is in addition to the requirement under section 7 of the ESA that federal agencies ensure their actions do not jeopardize the continued existence of listed species.

Species Description and Life History

General Overview

Humpback whales (*Megaptera novaeangliae* (Borowski 1781)) are large, baleen whales (family Balaenopteridae) that are found in all oceans across the globe. They range in color from black to gray with varying amounts of white on their bellies, flukes, and fins. Some patterns of color variation may occur among geographic regions, but variations also occur among individual whales. Distinctive natural markings on the underside of the fluke along with other identifying features such as scars have been used to identify individual whales for decades by cetologists around the world. Also among their distinctive traits are their long flippers, which are knobbed on the leading edge, and both flippers and fluke are scalloped on the trailing edges. Humpback whales can weigh over 40 tons (Ohsumi 1966) and are on average, 13-15 meters in length at maturity (Chittleborough 1965, Mikhalev 1997). Females are longer than males by about 1 to 1.5 meters (Chittleborough 1965). The oldest known humpback whale was estimated to be about 95 years old (Chittleborough 1965, Gabriele *et al.* 2010). Average generation length has been estimated to be 21.5 years (Taylor *et al.* 2007), and adult survival rate is estimated to be between 0.87 – 1.00, depending on location and year (Barlow and Clapham 1997, Chaloupka *et al.* 1999, Mizroch *et al.* 2004).

For humpback whales in the Northern hemisphere, age at sexual maturity is reached between 5 to 16 years of age (Clapham 1992; Gabriele *et al.* 2007, 2017; Robbins 2007) and varies by individual and population. Calving intervals are between 1 to 5 years but are more commonly between 2 to 3 years (Wiley and Clapham 1993, Steiger and Calambokidis 2000, Gabriele *et al.* 2017). Annual calving can occur but is rare (Straley 1989). In separate studies, average annual calving rates have been estimated to be between 0.25 - 0.5 and 0.14 - 0.73 per female (Clapham and Mayo 1990, Steiger and Calambokidis 2000, Gabriele *et al.* 2017).

Humpback whales breed and calve in tropical/subtropical waters in the winter months, typically during January – May in the Northern hemisphere. After an 11-12 month gestation period, calves are born in

the low latitude breeding grounds (Matthews 1937). Lactation occurs for close to 11 months, with calves beginning to wean at around 6 months (in June or July in the Northern Hemisphere) and reaching full independence after about a year (Chittleborough 1958, 1965; Clapham and Mayo 1990). Males produce long, complex songs during the breeding season (Payne and McVay 1971), possibly to communicate their location and readiness to mate or to establish social order among males, or both (Tyack 1981, Darling and Bérubé 2001). Singing is typically heard on the breeding grounds but has also been detected during migration (Norris *et al.* 1999, Noad and Cato 2007) and on feeding grounds as well (Mattila *et al.* 1987, McSweeney *et al.* 1989, Clark and Clapham 2004, Stimpert *et al.* 2012, Magnúsdóttir *et al.* 2014). While on breeding grounds, humpback whales rarely feed (Baraff *et al.* 1991).

During warmer months of the year, whales that have migrated to their breeding areas will migrate back to temperate, higher latitude regions to feed and build up their fat and energy for the return migration, lactation, and breeding. While foraging, humpback whales feed on mainly euphausiids (krill) and small pelagic fish (Krieger and Wing 1984, Baker 1985, Kieckhefer 1992, Clapham *et al.* 1997).

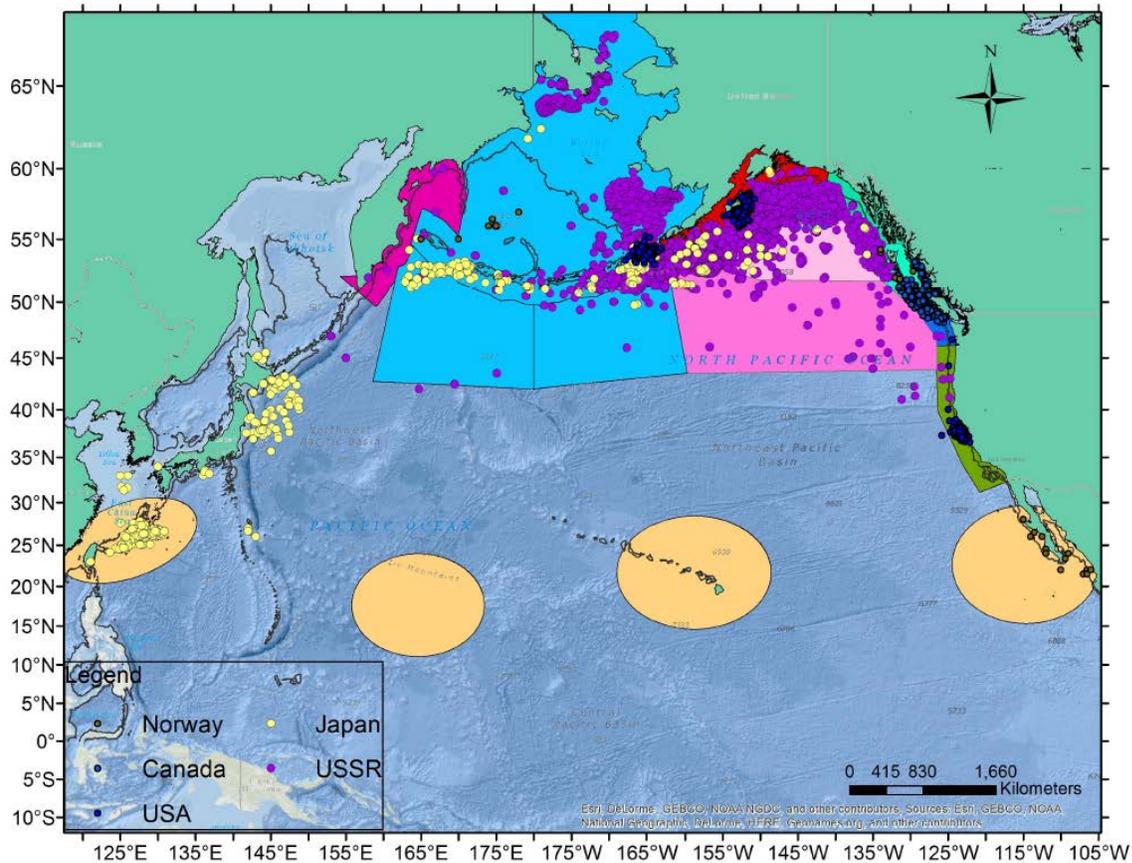


Figure 1. Distribution of humpback whale catches during the 20th century. Figure from Ivaschenko *et al.* (2015). Tan-colored ovals indicate the general location of some of the known breeding areas, and remaining colored polygons indicate the general location of feeding areas.

Humpback whales were commercially hunted for centuries throughout their range until the 1950s/60s. Reported catches from the 20th century suggest that humpback whales were distributed extensively throughout the North Pacific (Figure 1, Ivashchenko *et al.* 2015). Non-subsistence whaling was first prohibited by the International Whaling Commission (IWC) in 1955 in the North Atlantic and then in the North Pacific and Southern Hemisphere in 1965 after a final commercial whaling season (NMFS 1991). The total catch of humpback whales exploited in the North Pacific in the 20th century is estimated to be just over 29,000 whales (Ivashchenko *et al.* 2017). By the conclusion of modern whaling, the total abundance of humpback whales in the North Pacific may have been as few as roughly 1,000 whales (Rice 1978). Since the moratorium on commercial whaling, populations have been steadily increasing, but most have yet to return to historical abundance levels (Zerbini *et al.* 2006, Ford *et al.* 2009). Recent data (2013-2018) also suggest large declines in the reproductive rates for non-listed whales (i.e., Hawaii DPS) breeding off Maui, Hawaii (Cartwright *et al.* 2019). Despite reduced abundances, however, sightings data from systematic surveys conducted by NOAA from 1986 to 2005 indicate that humpback whales remain broadly distributed within the U.S. portion of their North Pacific range (Figure 2).

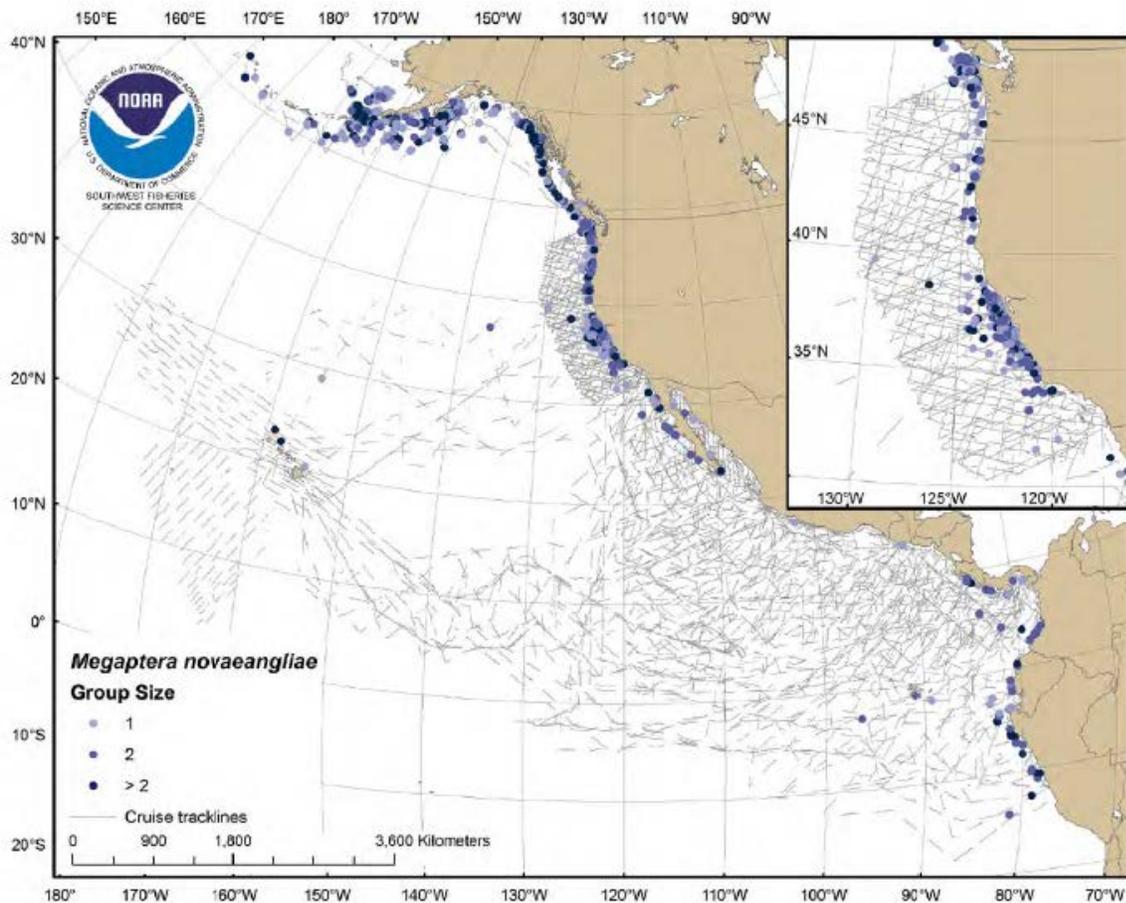


Figure 2. Cruise track-lines and locations of humpback whale sightings recorded during various surveys conducted by the NMFS Southwest Fisheries Science Center in the eastern Pacific Ocean from 1986 to 2005. Figure from Hamilton *et al.* (2009).

Distribution and Habitat Use

Breeding and Calving Areas

In the North Pacific Ocean, humpback whale populations breed and calve in tropical and semi-tropical waters during cooler months of the year. Specifically, whales from the Mexico DPS breed off the coast of Mexico, Revillagigedo Islands, and possibly Baja California Peninsula (Bettridge *et al.* 2015). (Although Baja California has been considered a breeding area, genetic evidence suggests that humpback whales in these waters are whales migrating to and from other Mexico breeding locations (Baker *et al.* 2013).) In the waters off of mainland Mexico and Baja California, the whales are present from November to June, while whales seem to arrive off the Revillagigedo Islands in September and leave in April-May (Urbán and Aguayo 1987). Whales from the Central America DPS breed off the coasts of Costa Rica, Panama, Guatemala, El Salvador, Honduras, and Nicaragua (Bettridge *et al.* 2015), with peak abundances generally occurring in January through March (Rasmussen *et al.* 2012). Humpback whales from the Western North Pacific DPS breed in waters around southern Japan (e.g., Okinawa and Ogasawara) from about December to June (Darling and Mori 1993), off the Philippines in the Kuroshio Current from about November to May (Acebes *et al.* 2007), and in an additional unknown breeding ground in the Western North Pacific (Bettridge *et al.* 2015).

Humpback whale breeding areas are characterized by warm, shallow waters (Clapham and Mead 1999, Ersts and Rosenbaum 2003, Rasmussen *et al.* 2007), and the whales are often found in association with islands, banks, or offshore reefs (Dawbin 1966, Whitehead and Moore 1982, Baker *et al.* 1986). For example, results of small boat surveys conducted annually from 1996 to 2003 off of Costa Rica and Panama indicated that 75% of all humpback whale sightings occurred at depths < 50 m and the average sea surface temperature across all years was 28.6° C (83.5° F, Rasmussen *et al.* 2012). In this study, most of the sightings in waters < 30 m were of calves (Rasmussen *et al.* 2012). These warm, tropical and subtropical breeding areas have low productivity, thus limited food availability, and the whales typically do not feed while on the breeding grounds - though it can occur (Rasmussen *et al.* 2012, Villegas-Zurita and Castillejos-Moguel 2013).

Within the North Pacific, humpback whales have relatively moderate to high levels of fidelity to particular breeding regions. For example, in a photo-identification study conducted from 1990 to 1993, inter-annual re-sighting rates of uniquely identified whales were as high as 0.39 for the Asia breeding region (Western North Pacific DPS), 0.12 for the Hawaii breeding region (non-listed Hawaii DPS), and 0.11 in the Mexico breeding region (Mexico DPS), with only a small number of individual whales observed at more than one breeding region across the three breeding seasons (Calambokidis *et al.* 2001). Low frequencies of whales occurring in different breeding regions in different breeding seasons have also been observed in other studies (e.g., Darling and McSweeney 1985, Darling and Cerchio 1993, Salden *et al.* 1999). For example, in a multi-year, basin-wide study (i.e., the “Structure of Populations, Levels of Abundance, and Status of Humpbacks;” referred to as the “SPLASH study”), of 586 uniquely identified whales from the Asia breeding region, two were sighted in the Hawaii breeding region; and of 2,317 uniquely identified whales in Hawaii, 17 were also sighted in the Mexico breeding area (Calambokidis *et al.* 2008). Two individual whales, thought to be males, were observed to repeat this behavior of moving between breeding regions in subsequent years, suggesting that some whales may be

highly flexible in terms of their choice of wintering area (Salden *et al.* 1999). Almost all sightings of whales in different breeding regions have been reported for different years; however, Forestell and Urban (2007) observed a humpback whale in the Revillagigedo Islands, Mexico, and 51 days later, the whale was observed again in Hawaii. Detections of shared song composition among whales from different breeding locations along with presence of whales in mid-ocean tropical waters during the breeding season also suggest some form of interchange between the populations (Darling *et al.* 2019a and 2019b). Overall, while movements among breeding areas appear to be rare, they remain poorly understood in terms of their full extent and their biological significance.

Because critical habitat cannot be designated in foreign countries or in areas outside of U.S. jurisdiction (50 CFR 424.12(g)), and because the documented breeding areas for the three listed DPSs of humpback whales occur outside of U.S. jurisdiction, their breeding areas were not considered as potential critical habitat. We did, however, consider recent data that suggest that some WNP DPS whales may be using areas around the Mariana Islands as a breeding ground. Discussion of this recent information is provided in the later section, “Geographical Area Occupied by the Species.” Overall, these new data suggest that an area off Saipan may be part of the hypothesized “missing” breeding area for the WNP DPS, additional data are needed to fully resolve the extent to which whales from the WNP DPS are using areas around the Mariana Islands as a breeding/ calving habitat and to determine the essential features of these areas.

Feeding Areas

In the North Pacific Ocean, humpback whales feed in biologically productive waters along the U.S. West Coast, British Columbia, and Alaska, as well as in waters off of Russia (e.g. Kamchatka, Commander Islands). Although these feeding areas are broadly distributed and range widely in terms of latitude, they are usually over the continental shelf or near the shelf edge at shallow (~10 m) to moderate water depths (~ 50 -200 m) and in cooler waters (Zerbini *et al.* 2016, Becker *et al.* 2016 and 2017). Often, feeding areas are also associated with oceanographic, topographic, or biological features (e.g., spawning runs) that serve to concentrate or aggregate prey (e.g., Tynan *et al.* 2005, Dalla Rosa *et al.* 2012, Thompson *et al.* 2012, Chenoweth *et al.* 2017, Straley *et al.* 2018).

Within feeding areas along the coasts of Washington, Oregon, and California, humpback whales are most abundant during spring, summer, and fall months (Green *et al.* 1992, Calambokidis *et al.* 2015), although they are present in winter months as well (Dohl *et al.* 1983, Forney and Barlow 1998, Campbell *et al.* 2015). The whales tend to be distributed farther from shore in winter months, and sightings during this part of the year may include whales that are undergoing seasonal migrations (Forney and Barlow 1998, Oleson *et al.* 2009, Becker *et al.* 2017). In general, humpback whales occur in varying water depths and are unevenly distributed over the continental shelf and along the shelf edge (Green *et al.* 1992, Calambokidis *et al.* 2015). Bathymetric features along this portion of the U.S. West Coast, in combination with other factors like coastal geomorphology and upwelling, have been shown to facilitate formation of near-surface aggregations of humpback prey species (Tynan *et al.* 2005, Santora *et al.* 2011), and submarine canyons, in particular, have been associated with krill “hotspots” (Santora *et al.*

2018; see “Diet and Feeding Behavior,” below). Such physical features are thus likely to also influence humpback whale distributions. For example, extensive aerial surveys conducted off the coasts of Washington and Oregon from April 1989 to October 1990, indicated that the whales were particularly clustered along the southern edge of Heceta Bank off of Oregon and in the steeply sloped waters associated with submarine canyons off of Washington (Astoria, Grays, and Nitinat Canyons, Green *et al.* 1992). Off the coast of California, based on 6 years of survey data collected during 1991- 1997, humpback whale concentrations are typically high in waters around the Farallon Islands, north and south of San Francisco Bay, and around Point Conception (Calambokidis and Barlow 2004) – all of which are highly productive areas where reoccurring krill hotspots have been documented (Santora *et al.* 2018).

Physical oceanographic mechanisms influencing primary productivity within these West Coast feeding areas (i.e., within the California Current Ecosystem (CCE)) are subject to significant variations on seasonal, inter-annual (e.g., El Niño), and decadal time scales (e.g., Pacific Decadal Oscillation (PDO) cycles; Barber and Chavez 1983, McGowan *et al.* 1998, 2003), adding variability to prey distribution and abundance within the feeding areas. Coastal upwelling, an important driver of primary productivity, also varies spatially along the extent of the California Current, with a narrower upwelling zone (~ 30 km wide) north of Cape Blanco (~42.8° N) relative to the upwelling zone farther south of this area, which can extend up to 100 km offshore (Huyer, 1983; Brodeur *et al.* , 2004). Off Southern California, upwelling occurs almost year round, and lasts for progressively shorter durations with increasing latitude (Bograd *et al.* 2009). Species distribution models that incorporate environmental variables have been used to predict humpback whale distributions within the CCE and indicate both seasonal and spatial shifts in distributions that are largely consistent with available humpback whale sightings data (e.g., Dalla Rosa *et al.* 2012, Becker *et al.* 2016, 2017). Cruises conducted in the northern CCE in June and August of 2000, which involved collection of cetacean sightings data as well as hydrographic and ecological variables, indicated that the distribution of humpback whales was significantly correlated with the position of alongshore upwelling, and that the whales occurred in both the relatively cool, saline, upwelled waters as well as in warmer waters (> 12° C) with intermediate salinities (Tynan *et al.* 2005). Among the five biological variables tested in their multiple logistic regression model, Tynan *et al.* (2005) found that values for chlorophyll maximums were most highly correlated with humpback whale occurrences in June and August, with zooplankton (as measure by integrated backscatter at 200 kHz) and larger prey such as fish (as measured by integrated backscatter at 38 kHz backscatter) also highly significantly correlated with humpback whale occurrences in June and August, respectively.

Southeast Alaska (SEA), which consists of a complex patchwork of islands, passes, and bays, is an area that provides diverse prey species for humpback whales, which typically arrive in this region in spring to target spawning aggregations of herring and reach peak abundances around late summer through early October or November, but can also be found in SEA in all months of the year (Baker *et al.* 1985, 1992; Straley 1990, 1994; Dahlheim *et al.* 2009; Straley *et al.* 2018). There is also evidence that a very small number of whales have overwintered in SEA and did not undergo their winter migrations to

breeding areas (Straley *et al.* 2018). Distribution and diet of the whales within SEA vary spatially and temporally in relationship with temporal and spatial variations in prey abundances (e.g., Bryant *et al.* 1981, Krieger and Wing 1986, Dahlheim *et al.* 2009, Straley *et al.* 2018, NPS unpublished data). In the spring, the whales congregate in particular areas, and then become more widely distributed during the summer months and make use of the various habitat types within this region (secluded bays and inlets, open-ocean, near-shore waters, etc., Dahlheim *et al.* 2009). In general, euphausiids appear to comprise the bulk of the humpback diet in SEA (Krieger and Wing 1986, Witteveen *et al.* 2011), but Pacific herring, as well as capelin, juvenile walleye pollock are also important components of the diet (Krieger and Wing 1986, Straley *et al.* 2018). More detailed information regarding diet composition of the whales by region is provided in the “Diet and Feeding Behavior” section of this report.

Within the northern Gulf of Alaska, Prince William Sound (PWS), has been surveyed extensively and has been recognized as an important feeding area for humpback whales (Teerlink *et al.* 2015, Ferguson *et al.* 2015a, Moran and Straley 2018). Humpback whales are present year-round in PWS, with highest abundances occurring in the spring and fall months and corresponding to when herring are spawning or aggregating (Moran and Straley 2018). Data from surveys of PWS conducted in September to March of 2007-2009 indicated that humpback whale abundance remained high throughout the fall and began to decline in late December to early January (Straley *et al.* 2018). The peak abundances of humpback whales during these surveys corresponded with the peak abundances of overwintering Pacific herring (Straley *et al.* 2018; Moran and Straley 2018). As with SEA, a small number of whales (under 2%, n= 4) have been observed to forego their winter migration and overwinter in PWS (Rice *et al.* 2011, Straley *et al.* 2018).

Elsewhere within the Gulf of Alaska, extensive surveys around the Kodiak Archipelago indicate that this area consistently supports feeding aggregations of humpback whales. Opportunistic aerial surveys conducted over a 17-year period beginning in 1999 as part of the University of Alaska’s Gulf Apex Predator-prey (GAP) study indicate that humpback whales were present in this area during every month of the year, with highest abundances occurring from July through September (Witteveen pers. comm, cited in Ferguson *et al.* 2015a; Witteveen and Wynn 2016). A stable isotope analysis, conducted over three years from 2004 to 2006, indicates that during this study humpback whales around Kodiak Island had a mixed diet of zooplankton and fish, with fish species likely comprising the bulk of diet (e.g., juvenile walleye pollock, capelin, and Pacific sand lance, Witteveen *et al.* 2011a).

To the west of the Kodiak Archipelago, multiple studies have noted aggregations of humpback whales around the Shumagin Islands, as well as around the eastern Aleutian Islands. Vessel surveys in 14 feeding seasons around the Shumagin Islands (conducted as part of the GAP study), from 1999 – 2015 (with an average of 5.6 effort days per season), and small boat surveys conducted during the summers of 1999 to 2000 indicate that the waters around the Shumagin Islands consistently serve as foraging habitat for humpback whales (Witteveen *et al.* 2004, Witteveen and Wynne 2013). Peak densities of humpback whales in this area occur in summer, from late July through August (Ferguson *et al.* 2015a). Based on multiple, systematic line-transect surveys, high densities of humpback whales are also known

to occur in waters around the eastern Aleutian Islands and in the southeastern Bering Sea from about June through September (Zerbini *et al.* 2006, Clapham *et al.* 2012, Friday *et al.* 2012, 2013). Based on systematic surveys in August of 1994 that extended 200 nmi (370.4 km) along the south side of the Aleutian Islands, between Kodiak Island and Tanaga Island, Forney and Brownell (1996) reported that humpback whales, which were the most abundant of the large whales they observed, were concentrated in the eastern portion of the study area and were more often sighted in deep waters over the Aleutian Trench or Aleutian Abyssal Plane. On the north side of the islands, the whales tend to occur close to shore or along the 50-m and 100-m isobaths (Moore *et al.* 2002, Zerbini *et al.* 2006, Friday *et al.* 2012, 2013), but are also commonly seen in deeper waters near Unimak Pass (Sinclair *et al.* 2005, Moore *et al.* 2002). Preferred habitat for humpback whales in the eastern Bering Sea may be areas associated with fronts where prey are more abundant or are more aggregated (Friday *et al.* 2012, 2013). Along the Aleutian Islands, humpback whales are rarely seen west of Umnak Island and Samalga Pass (Sinclair *et al.* 2005, Zerbini *et al.* 2006), which is considered to be a major transition zone between ecosystems and is reflected in differing distributional patterns of other organisms as well (Hunt and Stabeno 2005; Ladd *et al.* 2005).

Fidelity to Feeding Areas

Although these feeding areas off the U.S. West Coast (considered as Washington, Oregon, and California) and Alaska have an almost continuous distribution around the North Pacific basin, multiple studies have indicated relatively high levels of fidelity of whales to particular areas and limited movement of whales among feeding areas. These lines of evidence have led to various efforts to describe or delineate specific feeding areas or feeding “populations” of humpback whales. Along the U.S. West Coast, the most recent data suggest that there are two relatively separate feeding groups - one ranging over Oregon and California and one ranging from Washington to British Columbia (Calambokidis *et al.* 2008, Oleson *et al.* 2009, Barlow *et al.* 2011). Spatial structuring of feeding areas along the West Coast has been informed in large part by results of the SPLASH study, which involved the collection of both photographic and genetic data throughout the North Pacific by several hundred researchers working in over 10 countries (Calambokidis *et al.* 2008). Through the SPLASH study, photo-identification data were collected over three breeding seasons (2004, 2005, and 2006) and over two feeding seasons (2004, 2005) in six breeding areas and six feeding areas (Figure 3). Analysis of the photo-identification data revealed that both within-season and between-season movement of whales between feeding areas were infrequent and any such exchanges were mainly to adjacent areas, which is consistent with previous findings from earlier region-wide studies (e.g., Calambokidis *et al.* 1996, Calambokidis *et al.* 2001). For example, of 253 whales photo-identified in the California-Oregon feeding area in 2004, 47 of the 48 whales re-sighted in 2005 were sighted in the California-Oregon area (Calambokidis *et al.* 2008). The remaining whale was observed in the adjacent northern Washington/Southern British Columbia feeding area (see Table 1). In addition, during the 2004 feeding season, when survey effort was greatest, out of 789 whales that were seen on more than one day, only 5% (n= 42 whales) were seen in more than one of the defined feeding locations, and no interchanges of whales between the two West Coast feeding areas were observed (Calambokidis *et al.* 2008). These results are

similar to earlier sighting data from 1989-2002 where only 9% of whales (17 of 191 unique individuals) identified in surveys off the northern coast of Washington were also observed off of Oregon and California (Calambokidis *et al.* 2004). Results of this study also indicated that of the 191 unique whales, 44% (83 whales) were re-sighted in the survey area in more than one year (Calambokidis *et al.* 2004).



Figure 3. The six summer feeding areas (blue) and six winter breeding areas (green) surveyed during the SPLASH study. (Lines connecting areas indicates cases in which the areas were considered as a single regional unit for purposes of some analyses.) Polygons approximate where SPLASH surveys occurred. The breeding areas labelled “Asia” correspond to the breeding areas for the Western North Pacific DPS of humpback whales. Figure taken from Wade *et al.* (2016).

Results of the SPLASH and other photo-identification studies have indicated similar levels of fidelity of humpback whales to feeding areas in Alaska and limited interchange among the separate feeding areas; however, structuring of feeding groups or populations of humpback whales across feeding areas in Alaska is not yet resolved. Combining samples collected during the SPLASH study with some additional samples collected within PWS in 2004-2005, Witteveen *et al.* 2011 applied multiple approaches (i.e., genetic, photo-identification, and stable isotope analyses) to examine the degree of discreteness among three areas within the Gulf of Alaska - Kodiak, PWS, and SEA. These researchers further subdivided the areas into “inshore” and “offshore” subareas (see Figure 4). In general, although some interchange was observed, movement between Kodiak, PWS and SEA was relatively minimal, and analysis of mtDNA indicated that haplotype frequencies were significantly different in all pair-wise comparisons of samples

collected in the nearshore waters of PWS, Kodiak, and SEA (Witteveen *et al.* 2011). These results are consistent with previous analyses of SPLASH data, which showed limited inter-annual movement of whales among the broader feeding areas and with observed interchange occurring mainly between adjacent areas (Table 1). In an earlier comprehensive study of the North Pacific feeding areas conducted by 16 research groups from 1990 to 1993, involving analysis of 2,712 uniquely identified whales, high rates of return to, and limited interchange between, feeding areas in all regions, including SEA and PWS, was reported (Calambokidis *et al.* 2001). Of 287 unique whales sighted in SEA during this study, 97 (34%) were re-sighted in SEA and only three whales were seen in other Alaska feeding grounds (PWS and Kodiak). Of the 87 unique whales sighted in PWS, 37 (43%) were re-sighted there, and only one was sighted at a different feeding area (Kodiak). Of the four total whales that were observed in more than one feeding area, only one whale was observed on more than one feeding areas in the same year (SEA and PWS, Calambokidis *et al.* 2001). Based on sightings within the western Gulf of Alaska and eastern Aleutians from 1991 – 1994, Waite *et al.* (1999) also reported low rates of interchange of whales between the Kodiak region and PWS (4 of 127 unique whales) and between Kodiak and SEA (2 of 127 unique whales). There was no observed exchange of whales between the Shumagin Islands or the Eastern Aleutian Islands to other feeding locations, although very few whales were identified in these locations (22 and 7 whales respectively, Waite *et al.* 1999).

Table 1. Interchange among feeding areas based on humpback whale sightings in 2004 (rows) and 2005 (columns). The total number of photo-identified whales in each feeding area are indicated in column labeled “IDs.” The sampled feeding areas as labelled as follows: Aleut-Bering and Bering refer to the same Aleutian Islands/Bering Sea area; WGOA and NGOA are the western and northern Gulf of Alaska, respectively; SEAK refers to Southeast Alaska, NBC and SBC are northern and southern British Columbia, NWA is Northern Washington, and CA-OR refers to California and Oregon. Table taken from Calambokidis *et al.* (2008).

2004	IDs	2005							
		Russia	Bering	WGOA	NGOA	SEAK	NBC	SBC-NWA	CA-OR
Russia	40	72	301	111	427	482	236	152	319
Aleut-Bering	291	10	0	0	0	0	0	0	0
WGOA	223	0	41	0	0	0	0	0	0
NGOA	730	0	0	33	1	0	0	0	1
SEAK	808	0	0	6	119	1	0	0	0
NBC	421	0	0	1	4	175	16	0	0
SBC-NWA	76	0	0	0	1	13	74	4	0
CA-OR	253	0	0	0	0	0	1	21	1
		0	0	0	0	0	0	1	47

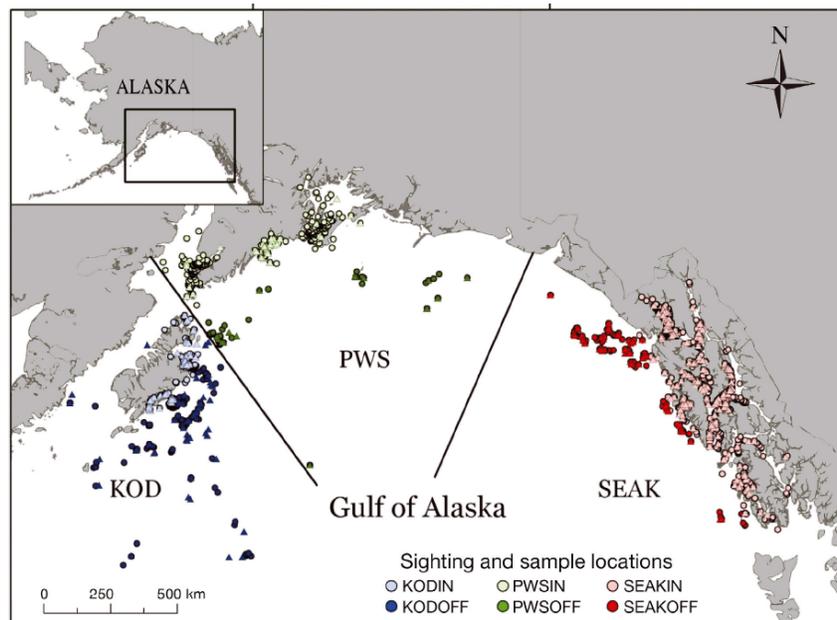


Figure 4. Sample regions and subregions applied by Witteveen *et al.* (2011) to evaluate the relationship among whales using feeding areas within the Gulf of Alaska. The three study regions are abbreviated as follows: KOD = Kodiak Archipelago; PWS= Prince William Sound, Kenai Fjords, and lower Cook Inlet; SEAK = southeastern Alaska; IN = inshore; OFF = offshore. Humpback whale sightings are indicated by circles, and location of biopsy samples are indicated by triangles. Figure from Witteveen *et al.* (2011).

For several well-studied areas in Alaska, analysis of long-term photo-identification records has provided additional information regarding the level of fidelity of humpback whales to feeding areas. In PWS in particular, photo-identification data collected from 1980 to 2009 indicated that, although 44.9% of the uniquely identified whales (182 of 405 whales) were seen only once, an almost equivalent number of whales (44.7%, 181 of 405 whales) were re-sighted in 2 to 10 years (von Ziesgesar 2013). An additional 9.8% of the whales (40 of 405) were sighted in 12 or more years of this 29-year study (von Ziesgesar 2013). Results of the GAP study, which extended over a 17-year period, indicated that humpback whales had an average annual rate of return of 34% to the Kodiak region (out of 1,187 unique whales over 17 seasons) and an average annual rate of return of 37% to the Shumagin Islands (out of 654 unique whales over 14 feeding seasons (Witteveen and Wynne 2016a). Ongoing, systematic summer surveys of Glacier Bay and the adjacent waters of Icy Strait have been conducted annually for more than 33 years and indicate similar levels of year-to-year fidelity of the whales in this portion of Southeast Alaska. For example, from 1985 to 2013, 63% of unique, non-calves were observed in the study area in more than one year (244 of 386 whales), and many whales were sighted each year (n=66; Gabriele *et al.* 2017). From 1985 to 2014, seven males and four females were sighted in the study area every year (Gabriele *et al.* 2017). Data from recent years (2014-2017), however, indicate a decline in returns of regularly sighted

whales (defined as whales seen in the area in at least 15 prior years) along with a decline in summertime abundances of humpback whales, which may be driven by declines in prey abundance or quality (Neilson *et al.* 2018).

Interestingly, some humpback whales appear to have a preference for specific locations within a feeding area. For example, von Ziegesar (2013) noted that some of the identified whales of PWS were often found in the same specific bay or passage within the sound, whereas other returning whales did not exhibit such specific site fidelity. Such site-specific preferences have also been reported in SEA (Baker *et al.* 1992, Gabriele *et al.* 1997, Sharpe 2001, Hendrix *et al.* 2012, NPS unpublished data).

Genetic analyses of 2,085 skin samples collected from 10 feeding locations and 8 breeding locations during the SPLASH study provided evidence of a significant degree of structuring of populations using the different feeding areas (Baker *et al.* 2013). From the tissue samples collected, a total of 1,855 unique whales were genotyped and analysis of maternally inherited mitochondrial (mt) DNA (for 1,010 whales) indicated highly significant differences in mtDNA haplotype frequencies among the feeding regions (overall $F_{ST} = 0.121$, $\Phi_{ST} = 0.178$, $p < 0.0001$; Baker *et al.* 2013). Differentiation was particularly high between the SEA and Oregon/ California feeding areas ($F_{ST} = 0.343$, Baker *et al.* 2013). In contrast, comparisons of bi-parentally inherited microsatellite DNA indicated weak but significant differentiation of microsatellite allele frequencies among feeding areas (overall $F_{ST} = 0.0034$, $p < 0.001$). The high degree of differentiation in mtDNA among feeding areas reflects the influence of maternal fidelity to feeding areas. This effect likely stems from the close dependency of calves on their mothers during their first year of life, during which they travel with their mothers and thereby inherit information from their mothers about feeding destinations (Baker *et al.* 1987, Pierszalowski *et al.* 2016).

Fine-Scale Usage Patterns

While most of our current understanding of humpback whale distributions in feeding areas is based on sightings data, satellite tagging of whales has provided additional, detailed information about the whales' use of, and movements within, their feeding habitats during a given feeding season. In the summers of 2007 to 2011, Kennedy *et al.* (2014) deployed satellite tags on eight adult humpback whales in Unalaska Bay, Alaska, and tracked the whales for an average of 28 days (range = 8–67 days). Position data were then analyzed and categorized into one of three possible behavioral modes: transiting; area-restricted searching (ARS), or unclassified. The slower speeds and higher turning angles during ARS behavior are considered to be indicative of active foraging (Kennedy *et al.* 2014, citing Kareiva and Odell 1987, Mayo and Marx 1990). Results indicated that whales mainly stayed over shelf and slope habitat (1,000 m or shallower) while in ARS mode, and all but one whale remained relatively close to Unalaska Bay during the tracking period (Figure 5). One whale, however, left Unalaska Bay 3 days after being tagged, traveling along the Bering Sea shelf towards Russia and covering almost 3,000 km in 26 days, indicating that the whales may in fact travel long distances during the feeding season (Kennedy *et al.* 2014).

Researchers from Oregon State University have conducted tagging efforts of humpback whales in various locations in the eastern North Pacific and analyzed ARS data to develop feeding-season “home ranges,” as they were termed for purposes of this study (Mate *et al.* 2018). These data are useful in providing a sense of both the overall size (to the extent of the tag duration) and variability in the size of the areas over which humpback whales will forage during a given season. To calculate these ARS ranges, the researchers first removed all the transiting location data from the satellite tracks for each whale, and then, using the remaining portions of tracks that contained at least 30 days of estimated locations, they produced 90% isopleths for each track and calculated the area of each whale’s resulting ARS range in GIS (Mate *et al.* 2018). Based on tracks for 7 whales tagged off of central California in the summer of 2017, ARS ranges averaged 17,684.4 km² (SE = 13,927.6 km²) and combined they extended from the Channel Islands in southern California to central Oregon (Mate *et al.* 2018, Figure 6). A slightly larger average ARS range had been calculated for eight

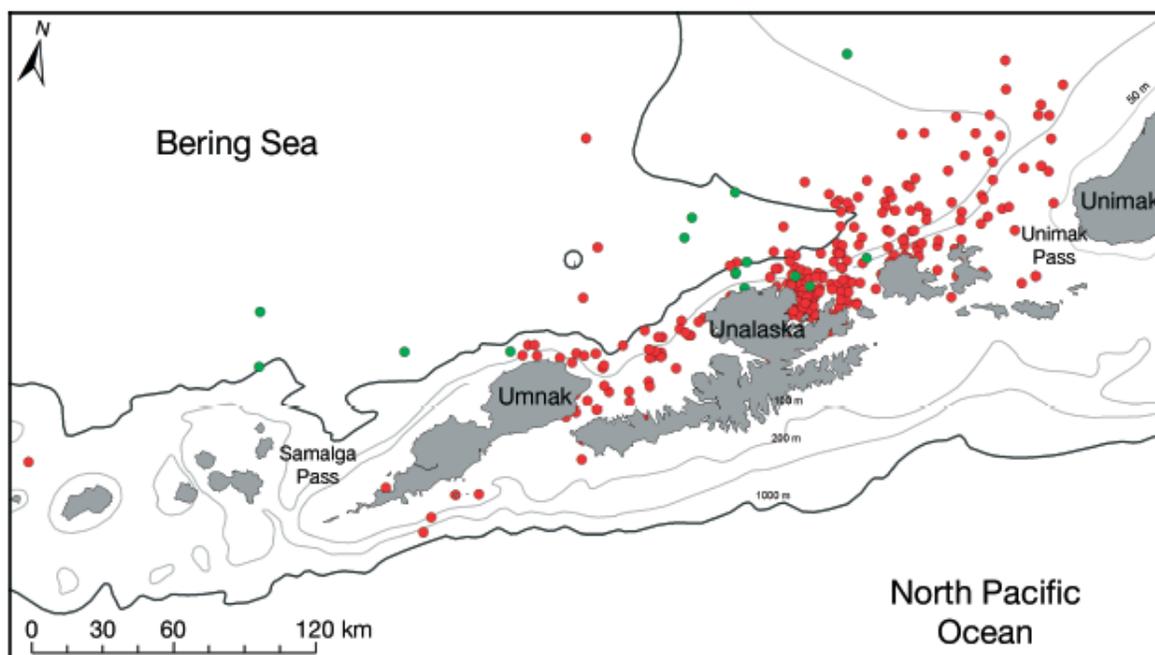


Figure 5. Locations of foraging (red circles) and travelling (green circles) modes for seven adult humpback whales tagged in Unalaska Bay, Alaska, during 2007 - 2011. Unclassified behavior modes are not shown. Figure from Kennedy *et al.* (2014).

humpback whales tagged previously by these researchers during the summer/fall of 2004 – 2005 (20,435.6 km², SE = 7322.8), which is consistent with reports that humpback whales were more widely dispersed in the CCE in 2005 (Mate *et al.* 2018). Based on tracks for four humpback whales tagged in September/ October off of the Oregon coast in 2017, average ARS ranges were comparable (17,215.6 km², SE = 8,430.6), with the combined ranges extending from Point Arena, central California, to the

southwest corner of Vancouver Island, British Columbia (Mate *et al.* 2018, Figure 7). In SEA, the average ARS range size for three whales tagged in Frederick Sound in summer of 1997 (4,904.3 km², SE = 1,728.8) was almost twice as large as the average ARS range size for four whales tagged in Frederick Sound and Seymour Canal in fall of 2014-2015 (2,862.7 km², SE = 1,834.2), likely reflecting a seasonal shift in target prey and prey distributions (see Figure 8; Witteveen *et al.* 2011, Straley *et al.* 2018). The two SEA average ARS ranges, however, were both much smaller than those calculated for the other West Coast locations. This result is difficult to interpret given the range of seasons of tagging efforts (spring, summer, and fall) in all areas, the durations of tag deployments in Alaska (averages of 28.2 days in 2014/15 (SE=4.7) and 38.6 days in 1997 (SE= 9.6) compared to the other West Coast deployments (e.g., averages of 44.1 (SE= 7.7), 56.8 (SE=10.9), and 61.8 (SE=14.4) days), and the small samples sizes in general. Overall though, these data indicate that humpback whales feed over sizeable areas while on the feeding grounds during a given season. The ARS ranges also correspond well to sightings data and further supported that the whales typically forage over shelf and shelf edge habitats (Mate *et al.* 2018).

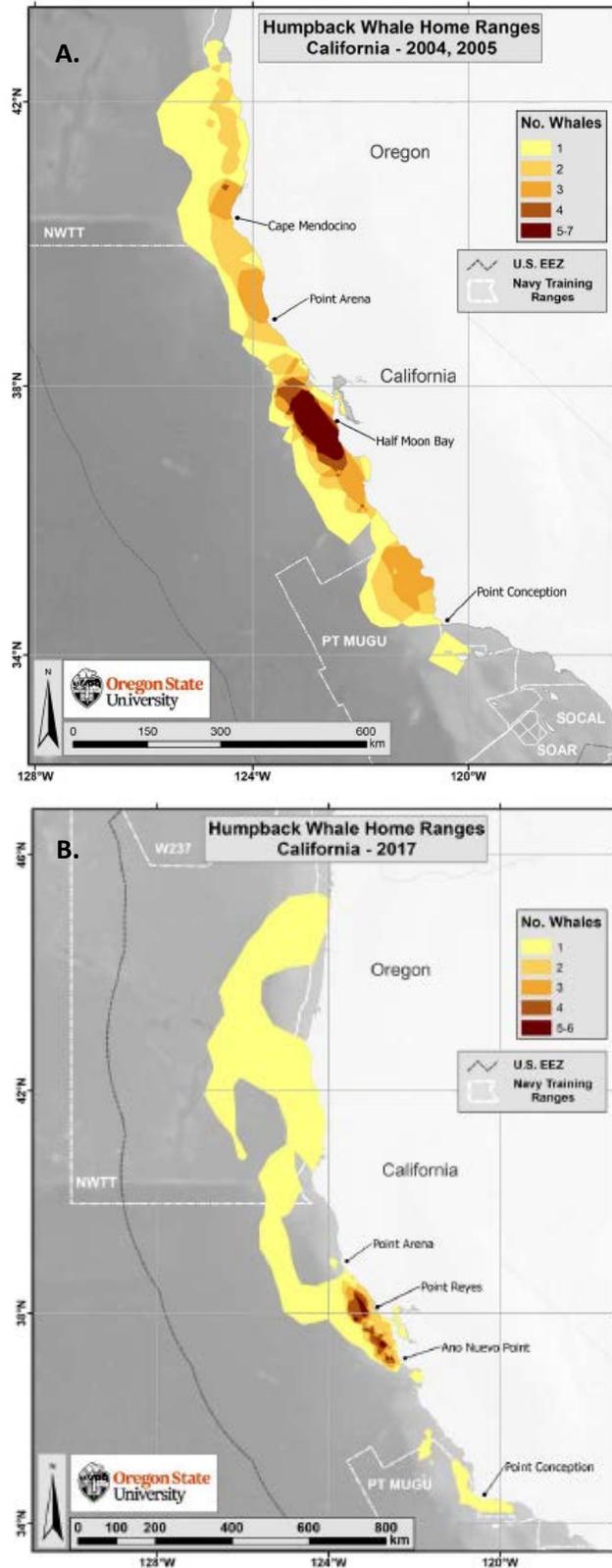


Figure 6. Feeding area ranges for (A) eight humpback whales tagged in summer/fall 2004-2005 and (B) for seven whales tagged in summer 2017 off central California. Shading corresponds to the number of individual whales with overlapping feeding ranges. Figures from Mate *et al.* (2018).

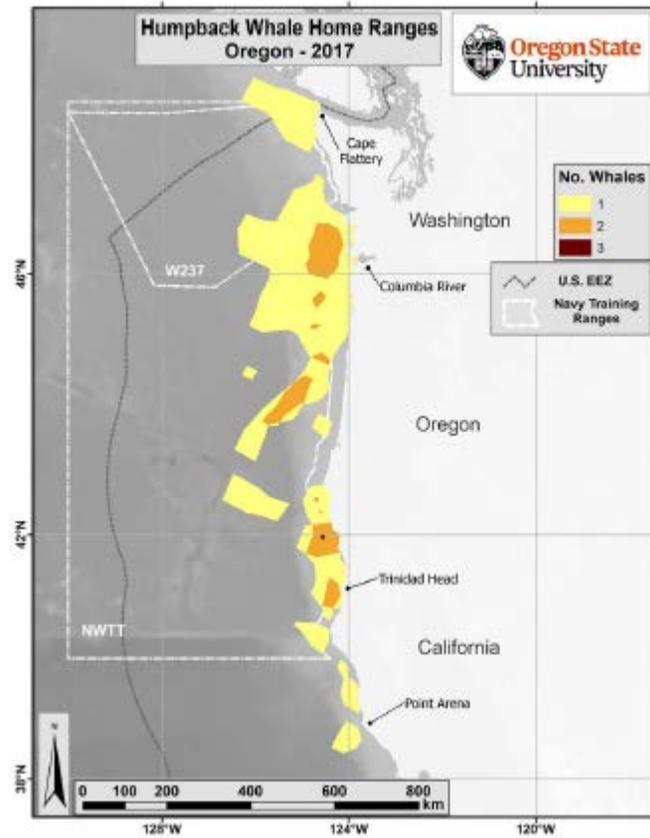


Figure 7. Feeding area ranges for four whales satellite-tagged off coastal Oregon during September – October, 2017. Figure from Mate *et al.* (2018).

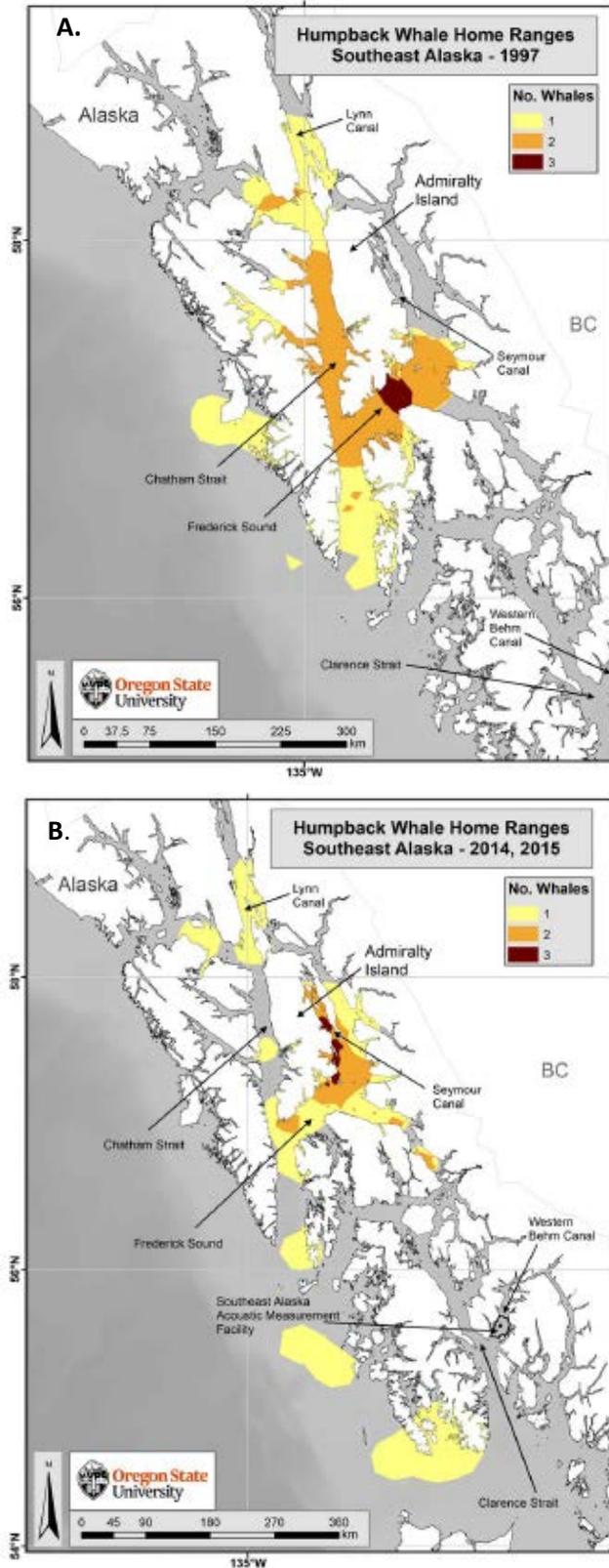


Figure 8. Feeding area ranges for (A) humpback whales tagged in Frederick Sound, Alaska in summer 1997 and (B) in Frederick Sound and Seymour Canal in fall 2014-2015. Shading corresponds to the number of individual whales with overlapping feeding ranges. Figures from Mate *et al.* (2018).

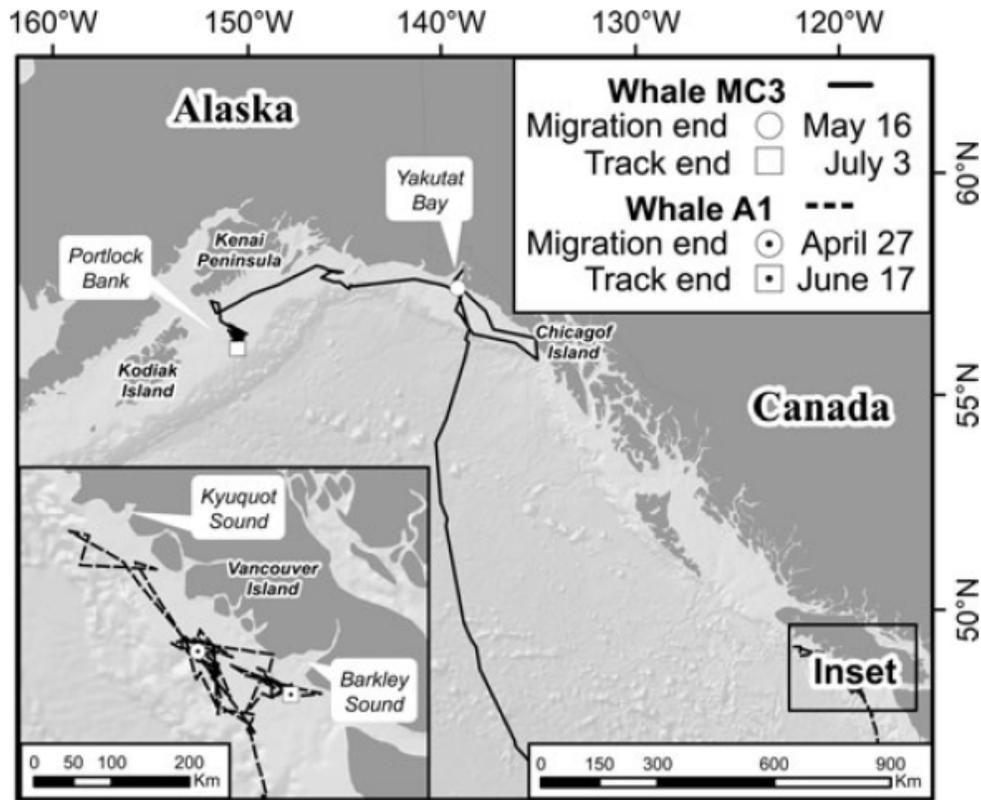


Figure 9. Movement tracks for an adult humpback (A1, inset) and a humpback calf (MC3) while on feeding grounds. Both whales were satellite tagged at Socorro Island, Mexico, in February 2003, and tracked up to the feeding areas. Figure from Lagerquist *et al.* (2008).

Some additional insights into fine-scale movements of whales in the feeding areas come from limited satellite telemetry data from whales that were tagged in their breeding areas, prior to undergoing their seasonal migrations. In February 2003, Lagerquist *et al.* (2008) tagged 11 humpback whales off Socorro Island in the Revillagigedo Archipelago, Mexico, and tracked two of these whales to feeding areas in British Columbia (46 day migration) and Alaska (49 day migration). One of these two whales, an adult, ended its migration off Vancouver Island and spent the next 19 days along the edge of the continental shelf west of the central coast of the island, before making an excursion 135 km northwest along the shelf edge to an area off Kyuquot Sound, where it then spent the next 6 days (Figure 9). The other whale, a calf (traveling with its mother), ended its migration in Yakutat Bay, Alaska, in May and eventually travelled northwest to Portlock Bank, an area approximately 130 km southeast of the tip of the Kenai Peninsula, where it remained for at least another 30 days (Figure 9). Although these movements are based on two tagged whales (and a third adult female), these data do indicate that the whales can spend extended time within relatively small areas but also undergo much longer movements within a feeding season. These results also demonstrate that whales from the same breeding area do not necessarily travel to the same specific destination.

Migratory Areas

Connections and movements of whales between their seasonal habitat have been studied indirectly using genetic data and matching of individual photo-identified whales at feeding and breeding areas, but the specific migratory routes used by the whales remains poorly understood, especially in the North Pacific. Although data are limited, additional insights into migratory routes has been gained through the use of satellite-monitored radio tags deployed on whales that subsequently undertake their seasonal migrations. Humpback whales were initially thought to migrate along a coastal route when travelling between their seasonal habitats, but migration routes are now known to be varied, with some whales taking coastal routes and some taking pelagic routes (Fleming and Jackson 2011). As mentioned previously, Lagerquist *et al.* (2008) tagged 11 whales off of Socorro Island, Mexico (within the Revillagigedo Archipelago) in February 2003, and data from these whales provides some insight into migratory routes. After an average of 13.6 days following tagging (range = 3.8 - 27.0 days), seven of the tagged whales migrated to areas north of the breeding areas in Mexico - three were adult whales without a calf and four were adult females travelling with a calf (Figure 10). Two of these seven whales were tracked all the way to feeding grounds - one to British Columbia (46 d migration) and one to Alaska (49 d migration) (Figure 9). The migration routes were well offshore, averaging 444 km from the coast and ranging from 115 to 935 km from the coast (Lagerquist *et al.* 2008). One whale, which travelled the closest to shore overall, came within 41 km of Point Arena, California at the closest point along its migration (whale A1, Figure 10). An offshore north-bound migratory route between the Revillagigedo Archipelago and Alaska was also documented through visual and acoustic detections during a ship-based survey by Norris *et al.* (1999).

Southbound migration routes were recorded by researchers from Oregon State University, who conducted satellite tagging efforts in multiple feeding areas during 1997 - 2017 (Mate *et al.* 2018). Six of 88 tagged whales were tracked along their full migration route to breeding areas, and an additional 20 whales were tracked for the early portion of their migration before transmissions ceased (see Figure 11). These tagging efforts indicate that up to three different migration routes were taken by whales departing from SEA, with most (n= 20) heading towards breeding grounds in Hawaii, one that headed west into the Gulf of Alaska, and two that headed south along the U.S West Coast (Figure 11A). One whale that had been tagged in 2017 off the coast of Oregon was tracked southward along a route that eventually extended well offshore before heading on an eastward trajectory towards mainland Mexico (Figure 11B). Another two whales that had been tagged off central California in 2004/ 05, took much more coastal routes southward to Mexico and Guatemala (Figure 11B).

Debate remains regarding whether some breeding areas may in fact also be locations along the migrations routes for some humpback whales. For instance, some available data suggest Baja California, Mexico and Ogasawara Islands, Japan (also called the Bonin Islands), both of which are considered breeding regions, are also part of typical migratory routes for some whales (Fleming and Jackson 2011). Lagerquist *et al.* (2008) reported that five of seven whales tagged off Socorro Island, Mexico, visited the

southern tip of Baja California on their way to areas to the north. (As shown in Figure 10, one also visited mainland Mexico before heading northward.) It has similarly been hypothesized that whales may be using the Ogasawara region as a migratory stop-over on their way to Okinawa Island or to hypothesized breeding areas in the Southwest Pacific (Fleming and Jackson 2011, Bettridge *et al.* 2015).

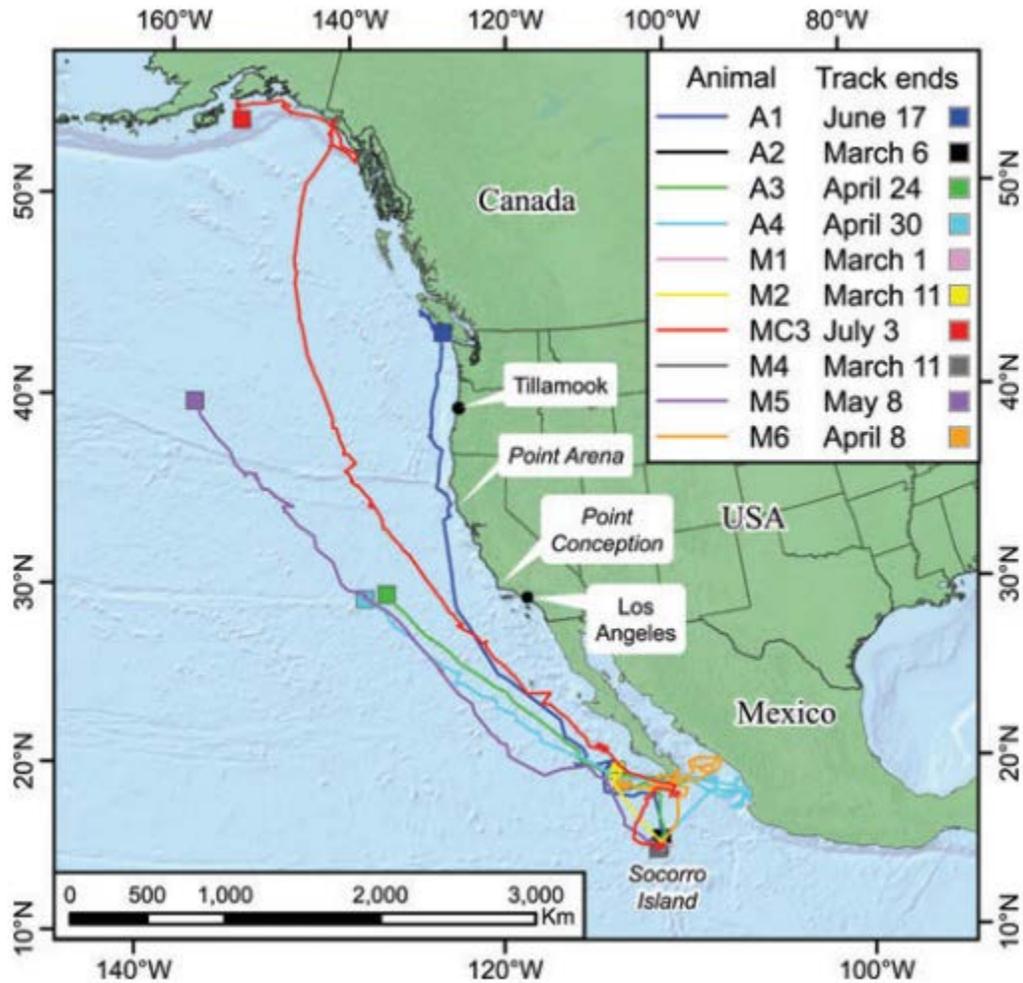


Figure 10. Migratory routes of 10 whales satellite tagged off of Socorro Island, Mexico in February 2003. Figure from Lagerquist *et al.* (2008).

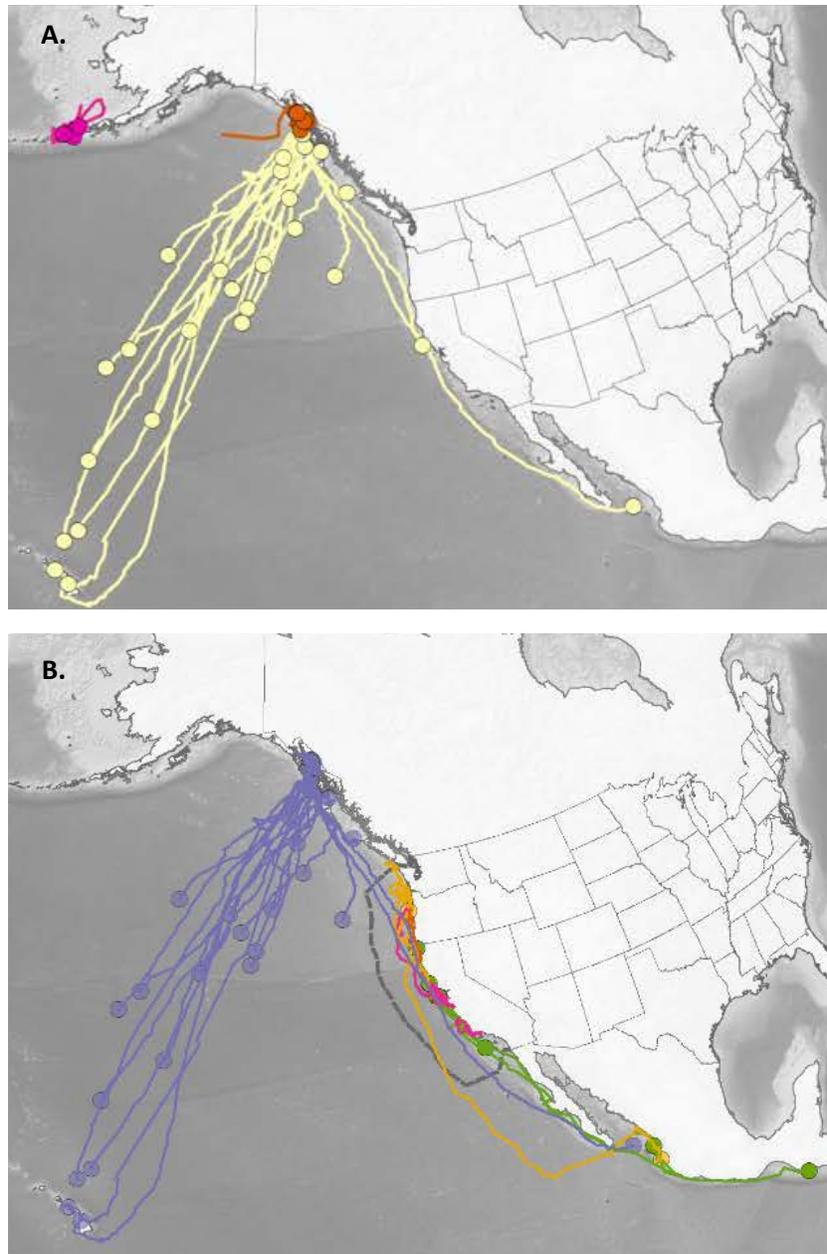


Figure 11. Movements for (A) humpback whales satellite tagged in Southeast Alaska (SEA, n=48) and off Dutch Harbor, Alaska (n=5). Colors correspond to tag deployment years as follows: yellow = 2014-15, pink = 2008, and orange = 1997. (B) Satellite-tag tracks for humpback whale tagged off of central CA (n= 29) and OR (n=8), as well as SEA in 2014-2015 (which are also shown in (A)). Colors correspond to the following years of tag deployments from CA and OR: pink = 2017, orange = 2017, green = 2004/2005. U.S. EEZ off the U.S. West Coast shown as gray, dashed line in (B). Figures from Mate *et al.* (2018).

Timing of migrations between feeding and breeding areas appears to vary with age, sex, and reproductive status of the whales (Chittleborough 1965, Dawbin 1997, Brown *et al.* 1995). Based on an extensive review of whaling records for 65,600 whales captured in the southern hemisphere, Dawbin (1997) concluded that, on average, lactating females with weaning yearling calves were the first to undergo migrations northward, followed by juveniles, then mature males, and lastly by pregnant females. Dawbin (1997) also found the whales underwent the return migrations southward in the same general order in which they arrived in their northern habitats. In Hawaii, females without calves appear to arrive and leave the winter breeding grounds first, generally followed by juveniles, then males, and then females with calves (Craig *et al.* 2003). Migratory behaviors may, however, differ among humpback whale populations. For example, somewhat inconsistent patterns have been described for humpback whales in the Atlantic in comparison to those in the Pacific (e.g., Stevick *et al.* 2003). Also, in contrast to findings for whales departing from Hawaii, Lagerquist *et al.* (2008) reported that there was no difference in the departure dates between whales travelling with and without calves from Mexico breeding areas (n=7 whales total). Differences in timing of migrations among whales within a population could potentially result in slightly different migratory choices or routes; however, data to evaluate this possibility for the listed DPSs of humpback whales in the North Pacific are not available.

Diet and Feeding Behavior

Within the Northern Pacific, humpback whale diet consists predominantly of euphausiids (krill), specifically *Euphausia*, *Thysanoessa*, *Nyctiphanes*, and *Nematoscelis*, and small pelagic schooling fish species (Krieger and Wing 1984, Baker 1985, Kieckhefer 1992, Clapham *et al.* 1997). Detailed diet information comes from decades-old studies involving direct analysis of stomach contents of humpback whales taken through whaling activities. More recent diet studies are available, however, and employ indirect methods (e.g., stable isotope analyses of tissue samples, acoustic assessments) to classify prey, or provide observational information (e.g., plankton tows within feeding areas, analysis of dive behaviors). Despite methodological differences among the available diet studies, the existing literature consistently supports the conclusion that humpback whales primarily consume euphausiids and small, schooling pelagic fish species (Nemoto 1957,1959; Klumov 1963; Rice 1963; Krieger and Wing 1984; Clapham *et al.* 1997). Humpback whales are generalists, taking a variety of prey while foraging and also switching between target prey depending on what is most abundant or of highest quality in the system (Witteveen *et al.* 2015, Fleming *et al.* 2016). Therefore, while humpback whales will consume most or all species listed below, their diet composition will vary spatially and temporally. Here, we present a comprehensive overview of diet information for the three listed DPSs of humpback whales by major feeding areas of the North Pacific. Tables A1- A4 in Appendix A provide more comprehensive lists of diet studies and reported prey by region.

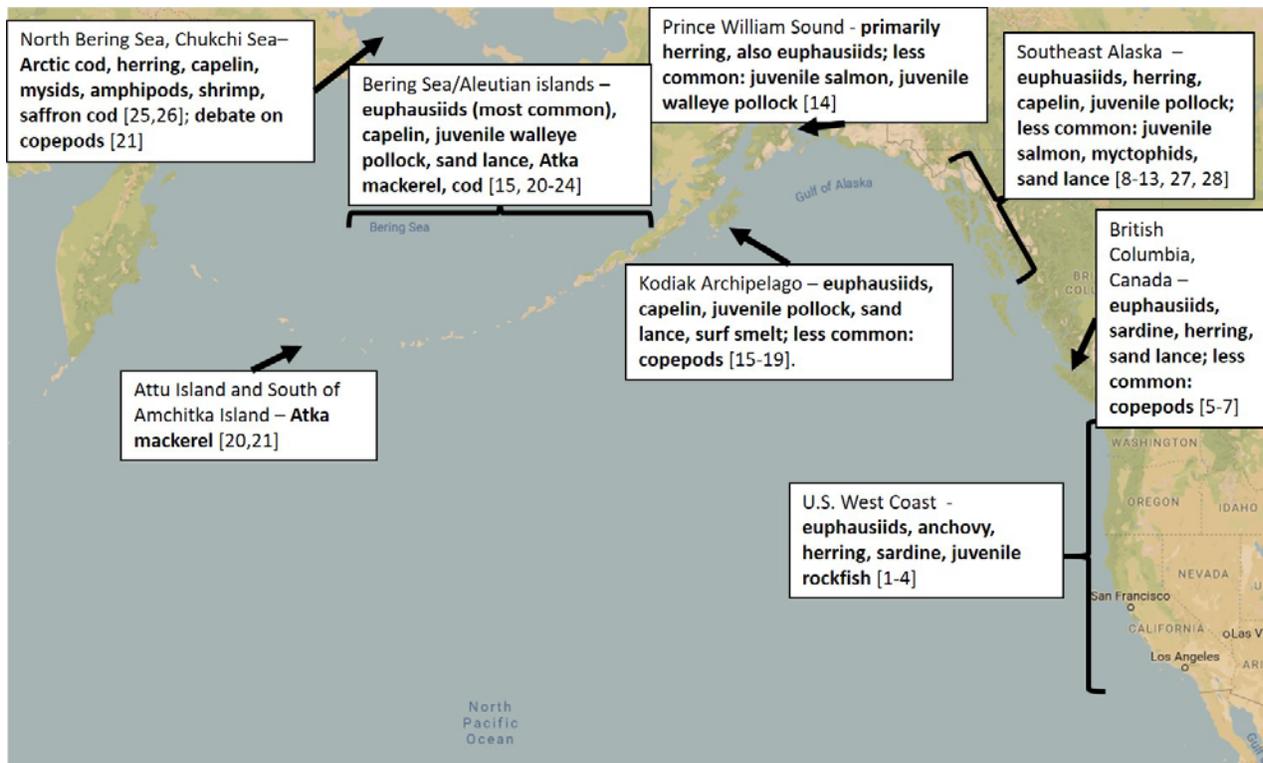


Figure 12. Major humpback whale prey species reported for locations in the Eastern and Northeastern Pacific Ocean. Includes prey noted in stomach analyses, stable isotope, and prey that were observed to be consumed by humpback whales. More comprehensive lists of all potential prey for each region can be found in Appendix A along with scientific names for prey species. References corresponding to numbers shown in the figure are as follows: **1.** Rice 1963; **2.** Kieckhefer 1992; **3.** Clapham *et al.* 1997; **4.** Fleming *et al.* 2016; **5.** Andrews 1909; **6.** Ford *et al.* 2009; **7.** Fisheries and Oceans Canada 2013; **8.** Jurasz and Jurasz 1979; **9.** Krieger and Wing 1984; **10.** Baker *et al.* 1985; **11.** Moran *et al.* 2018; **12.** Doherty and Neilson 2012; **13.** Doherty and Gabriele 2012; **14.** Moran and Straley 2018; **15.** Thompson 1940; **16.** Witteveen *et al.* 2006; **17.** Witteveen *et al.* 2008; **18.** Witteveen *et al.* 2012; **19.** Wright *et al.* 2016; **20-22.** Nemoto 1957, 1959, 1978; **23.** Nemoto and Kawamura 1977; **24.** Wynne *et al.* 2013; **25.** Tomilin 1967 as cited in Kawamura 1980; **26.** Klumov 1963; **27.** Chenoweth *et al.* 2017; **28.** Gabriele *et al.* 2017.

U.S. West Coast (California, Oregon, and Washington)

Prey targeted by humpback whales foraging in the CCE include Pacific sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*), Pacific herring (*Clupea pallasii*), euphausiids (specifically *Thysanoessa*, *Euphausia*, *Nyctiphanes*, and *Nematoscelis*), and occasionally juvenile rockfish (*Sebastes*; Rice 1963, Kieckhefer 1992, Clapham *et al.* 1997; see Table A1). Clapham *et al.* (1997) examined log books from whaling ships from the 1920s that documented stomach contents for 1,542 whales caught off California (Moss Landing and Trinidad). The majority of stomachs were reported as containing sardines and euphausiids (recorded as “shrimp” but presumed to be euphausiids based on

contemporary observations). Some contained anchovies, herring, milk, unidentified fish, and “other;” 187 stomachs were empty. Rice (1963) analyzed stomach contents of 149 humpback whales captured off central California during 1959-1962. Over 60% of the stomachs contained anchovies and 36% contained euphausiids (specifically *Euphausia pacifica*), while there were trace amounts of herring and euphausiids, *Thysanoessa spinifera*. Between these two studies, there is a notable shift in diet from mainly sardine in the 1920s to mainly anchovy in the 1950s and 1960s, a time-period in which sardine biomass in the region was extremely low (see Chavez *et al.* (2003).

More recent studies have typically had to employ methods other than direct stomach content analysis to assess humpback whale diet but have found similar prey as older studies for humpback whales in California. Kieckhefer (1992) observed daytime feeding behaviors of whales during 1988-1990 within the Gulf of the Farallones region and also collected fecal samples. Whales were observed feeding on euphausiids and analysis of 11 fecal samples confirmed that target prey consisted of mainly *T. spinifera*, followed by *E. pacifica*, and also some *Nyctiphanes simplex* and *Nematoscelis difficilis* (Kieckhefer 1992). Whales were also observed feeding on herring, juvenile rockfish, and anchovy. Fleming *et al.* (2016) collected 259 skin samples during 1993-2012 from whales throughout the CCE (between 34°N and 42°N) and used stable isotope analysis (stable carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$)) to evaluate the relative contribution of euphausiids versus fish to the diet. In this study, shifts over the 20 year time period in isotope signatures in whale skin samples indicate trophic-level shifts in the humpback whale diet, and these shifts corresponded to shifts in relative prey abundance (krill versus anchovy and sardine) and changing oceanographic conditions within the CCE. These results suggest that the dominant prey in humpback whale diet switched from krill to fish, and back to krill during the 20-year period, depending on the relative abundance of each prey. Based on previously published isotope values, the authors found that anchovy and sardine values were similar to isotope signatures in humpback whale samples in fish dominant years and carbon values were correlated with anchovy abundance, suggesting whales were consuming these fish species. Although, isotope values and abundance of other small schooling fish species were not examined in this study, recent anecdotal information lends additional support to the interpretation that humpback whales are consuming anchovy.

Over the past five years, anecdotal observations of humpback whales feeding very nearshore, not only in Monterey Bay, but also under the Golden Gate Bridge and along shorelines and beaches to the north have been reported by local news outlets. This nearshore distribution may be related to anchovy or other prey species, but it is currently unknown what these whales are targeting (pers. comm., W. Sydeman, Farallon Institute, 12/6/2018). Some of the anecdotal reports have stated that the whales are feeding specifically on anchovy in this area (mainly Monterey Bay) (e.g., ([1] <https://baynature.org/2013/10/04/anchovies-spark-humpback-feeding-frenzy-monterey-bay/> ; [2] <https://abc7news.com/pets-animals/humpback-whales-spotted-happily-feeding-in-monterey-bay/3849902/> ; [3] <https://www.mercurynews.com/2017/08/10/humpback-whales-gorge-in-monterey-bay/>

[bay/](#)). According to Calambokidis *et al.* (2017), whales feeding near shore in San Francisco Bay and in the Columbia River area are likely feeding on anchovy.

Farther north within the CCE, in British Columbia (B.C.), humpback whales have been observed feeding on sardine, herring, and euphausiids (Fisheries and Oceans Canada, 2013), as well as sand lance (*Ammodytes personatus*; Ford *et al.* 2009); however, no dedicated diet studies have been conducted in B.C. (pers. comm cited in Fisheries and Oceans 2013). Older studies from this region involving stomach content analysis showed that stomachs almost exclusively contained euphausiids (Andrews 1909). Another study that analyzed stomach contents for whales captured 1949-1965 indicated that 92% of humpback whale stomachs contained euphausiids and 4% contained copepods (Cetacean Research Program, Fisheries and Oceans Canada, unpubl. data cited in Ford *et al.* 2009).

As mentioned previously, the distribution and relative abundances of key prey species that occur within the CCE can shift from year to year (see “Feeding Areas,” above); however, some relatively consistent spatial patterns exist for krill. Hotspots with persistent, heightened abundances of krill occur within the CCE from the Strait of Juan de Fuca in Washington to San Diego, CA, largely in association with submarine canyons (Santora *et al.* 2018). Based on acoustic surveys conducted in 2000-2015 and geospatial analysis of bathymetric features, Santora *et al.* (2018) detected over 400 krill hotspots within the CCE. Reoccurring hotspots were frequently detected off Northern/Central California around Cape Mendocino, near the Gulf of the Farallones and Monterey Bay where canyons are particularly dense, and some were also observed farther north off Washington near the Strait of Juan de Fuca (Santora *et al.* 2018).

Distributions of forage fish within the CCE (anchovy, sardine, and herring) are fluid from year to year but have some general patterns based in part on season (related to spawning), ocean conditions (e.g., temperature, upwelling), and abundance. The population of northern anchovy along the U.S West Coast and into Canada and Mexico, has been divided into northern, central, and southern subpopulations based on differences in meristics (i.e., countable traits), morphology, and genetics (McHugh 1951, Vrooman *et al.* 1981). The northern subpopulation of northern anchovy extends from Eureka, California into British Columbia, the central subpopulation extends from northern California to Baja California, and the southern subpopulation range is outside of U.S. waters along the Baja peninsula (McHugh 1951). The extent of the northern subpopulation and areas of its highest density shift from year to year and seasonally both along the coast and in terms of distance from shore, which appears to be in relation to temperature (Litz *et al.* 2008). A summary of California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys suggests that the central subpopulation of anchovy are most abundant from San Francisco into Mexican waters and will spread over a larger region in spring during spawning and concentrate near the coast in summer/fall (Messersmith *et al.* 1969). More recent acoustic and trawl surveys conducted in multiple years from 2006-2016 within the CCE showed that anchovy in spring/summer, were variably distributed along the Washington, Oregon coast, and California coasts depending on year; and were consistently caught offshore of the Columbia River mouth and offshore of

Monterey Bay (Zwolinski *et al.* 2012, 2016, 2017). Pacific sardine extend from Baja California to Canada (Clark and Janssen 1945) and offshore to about 556 km (Macewicz and Abramenkoff 1993). Off of California, Pacific sardine are distributed farther from shore relative to spawning anchovy, likely due to differences in preferred spawning habitat based on water temperature and primary production (Lluch-Belda *et al.* 1991, Reiss *et al.* 2008). Patterns of sardine distribution along the coast are largely driven by temperature and spawning; sardine are concentrated offshore of California in spring during the spawning season (Clark and Janssen 1945), then move north to Oregon, Washington, and British Columbia likely due to temperature increases (McClatchie 2009) with occasional spawning in these areas depending on temperature (Emmett *et al.* 2005), and finally return to California in winter before spring spawning. This seasonal pattern was further confirmed by habitat models, fisheries catches, and acoustic-trawl surveys (Zwolinski *et al.* 2011, Demer *et al.* 2012). However, Demer *et al.* (2012) noted that in the 1940s when the Pacific sardine population crashed, sardine were concentrated off of southern California (MacCall 1976) and appeared to not migrate/expand in distribution until biomass recovered (McFarlane and Beamish 2001). Pacific herring occur from Washington to Southern California (McHugh 1954) and can be one of the most abundant, prevalent forage fish off Washington and Northern Oregon (Brodeur *et al.* 2005, Zwolinski *et al.* 2012).

In addition to inter-annual and longer-term variations in distributions, both krill and forage fish species may also undergo within-season changes in their distributions in response to upwelling, as was observed in a recent study conducted by Benoit-Bird *et al.* (2019) in Monterey Bay, California. In this study, both video and acoustic observations were used to monitor the distributions of prey within the upper 300 m of the water column. Results indicated that both krill and anchovy - the most abundant animal species observed - formed small, discrete aggregations on the scale of 10 m horizontally and a few to 100 m vertically during upwelling. These smaller patches were also clustered at the kilometer level scale into larger “hotspots” (Benoit-Bird *et al.* 2019). When upwelling relaxed, the krill and anchovy became more diffusely distributed. The observations also indicated that overall forage biomass did not change substantially as a result of day-to-day variation in upwelling; rather, it was the prey distributions that were affected by the strength of upwelling (Benoit-Bird *et al.* 2019). Although Benoit-Bird *et al.* (2019) did not measure predation, they did anecdotally note that they observed a greater abundance of actively foraging predators, such as sea birds and mammals, in their study area during strong upwelling.

Alaska

In waters off Alaska, the humpback diet includes euphausiids, capelin (*Mallotus villosus*), Pacific herring, Atka mackerel (*Pleurogrammus monopterygius*), juvenile walleye pollock (hereafter “pollock,” *Gadus chalcogrammus* (formerly, *Theragra chalcogramma*)), Pacific cod (*Gadus macrocephalus*), saffron cod (*Eleginus gracilis*), Arctic cod (*Boreogadus saida*), rockfish (*Sebastes*), Pacific sand lance (*Ammodytes* spp.), eulachon (*Thaleichthys pacificus*), surf smelt (*Hypomesus pretiosus*), Pacific sandfish (*Trichodon trichodon*), juvenile salmon (*Oncorhynchus* spp.) and myctophids (primarily *Stenobrachius leucopsarus*) (Nemoto 1959, Klumov 1965, Tomilin 1967, Krieger and Wing 1984, Baker 1985, Witteveen *et al.* 2008,

Neilson *et al.* 2015). Euphausiids consumed in Alaska are mainly from genus *Euphausia* and *Thysanoessa* (Krieger and Wing 1984). Additional prey noted in Alaska are mysids, amphipods (*Parathemisto libeellula*), and shrimps (*Eualus gaimardii* and *Pandalus goniurus*) (Tomilin 1967). In recent years in Southeast Alaska and Prince William Sound, there have also been observations of humpback whales feeding on hatchery released juvenile salmon (Chenoweth *et al.* 2017).

Prey availability, and thus humpback diet composition, vary both spatially and temporally across feeding areas in Alaska. Acoustic and trawl (Methot tows) surveys conducted over 4 years (in 2003, 2005, 2011, and 2013) indicated that euphausiids, which are found in high abundance throughout the Gulf of Alaska and eastern Bering Sea, are patchily distributed, and within localized areas, exhibit fairly large inter-annual fluctuations in abundance (Simonsen *et al.* 2016). Within the Gulf of Alaska (GOA), euphausiids appear to be more concentrated within coastal bays and troughs relative to broad, flat areas of the shelf (Simonsen *et al.* 2016). Based on acoustic and net surveys throughout the Bering Sea over six summers (2004 and 2006–2010), highest densities of euphausiid biomass typically occurred around the Southeastern portion of the shelf (Ressler *et al.* 2012). In terms of fish species, comprehensive information is provided in appendices for NMFS stock assessment and fishery evaluation reports (SAFE) for groundfish. These assessments show that Pacific herring are abundant throughout the GOA but rarely occur west of Kodiak Island, and mainly occur inshore and in the eastern Gulf, with concentrations or “hotspots” near Kodiak Island and in portions of Southeast Alaska (Ormseth 2014). Pacific herring also have varying distributions within the Bering Sea depending on time of year due to seasonal migrations (Ormseth 2015). In general, capelin occur throughout the GOA, but abundance is mainly concentrated in the central Gulf, off Kodiak Island and Portlock Bank, and rarely inshore; though they do occur in inland waters of Southeast Alaska and within Prince William Sound (Brown 2002, Arimitsu *et al.* 2008, Ormseth 2014, Ormseth *et al.* 2016). In the Bering Sea/Aleutian Islands (BSAI) region, capelin are distributed mainly in the inner portion of the Eastern Bering Sea (EBS) shelf. Pacific sand lance are difficult to sample but data suggest that they are distributed inshore in Bristol Bay and along the Alaska Peninsula (Ormseth 2015). Sand lance were mainly concentrated nearshore and in Western GOA, though unpublished data suggests that they are also present in the Eastern GOA. Sand lance are also found nearshore in Prince William Sound (Ostrand *et al.* 2005). More specific discussion on how these general regional patterns of prey distribution influence humpback whale diet composition is provided below.

Southeast Alaska

In Southeast Alaska, krill, herring, and capelin are the main prey of humpback whales (see Table A2). Jurasz and Jurasz (1979) observed humpback whales feeding in Lynn Canal, Frederick Sound, and Glacier Bay, over 12 years (1966-1978), and determined that whales were feeding on herring, krill (*Euphausia pacifica*), and capelin. Krieger and Wing (1984) observed whales foraging in multiple locations in 1983 and used both hydroacoustic surveys and trawl/net sampling to determine that whales were foraging on krill, herring, capelin, and juvenile pollock. These authors found that dominant prey varied among the specific locations within Southeast Alaska. Specifically, during this study, krill were the dominant prey in Stephens Passage, herring was the main prey in Icy Strait and in Frederick Sound, and capelin was the

main prey near Glacier Bay (Krieger and Wing 1984). (Applying the same survey techniques in the following year (1984), Krieger and Wing (1986) also demonstrated how these patterns can vary from year to year.) In Frederick Sound in 1981, Baker (1985) observed humpback whales feeding on herring and substantiated his observations with the hydroacoustics from Krieger and Wing (1984). Based on research conducted during the fall/winters of 2007-2009, whales foraged mainly on krill in Sitka Sound and mainly on herring in Lynn Canal (Rice *et al.* 2011, Moran *et al.* 2018). In Sitka Sound, whales were observed feeding on krill in the fall, while in winter, the same whales were found feeding on herring (Straley *et al.* 2018). Based on observations and sampling in the immediate vicinity of feeding whales, sand lance and myctophids have also been identified as target prey items in the Glacier Bay/ Icy Strait area (e.g., Gabriele *et al.* 2017, Neilson *et al.* 2017, Neilson and Gabriele 2006, 2008; Doherty and Gabriele 2002). Stable isotope analysis of skin samples (based on $\delta^{15}\text{N}$) collected during the feeding season (May – December), suggest that whales feeding in Southeast Alaska (n = 229) have a diet higher in zooplankton and lower in fish relative to whales feeding in the Prince William Sound (n= 52) and Kodiak regions (n = 147; Witteveen *et al.* 2011).

Prince William Sound

Diet of humpback whales in Prince William Sound has been monitored for over a decade using observations of humpback whales feeding, collection of prey remains after feedings, acoustic sampling of prey, and stable isotope analysis. From 2007 – 2015, herring was the dominant prey for humpback whales in Prince William Sound and comprised an estimated ~35% to 98% of the diet (Moran and Straley 2018). Euphausiids and other zooplankton (that may contain euphausiids) were also a prominent prey item, comprising up to 22% of the diet depending on year. Other prey consumed included juvenile coho salmon (*Oncorhynchus kisutch*) and walleye pollock at low proportions. Seasonally, herring was the dominant prey in all seasons but summer, when euphausiids dominated the diet (Moran and Straley 2018). The biomass of herring consumed by humpback whales in Prince William Sound was roughly equivalent to the herring biomass estimated to be lost as a result of natural mortality, suggesting that humpback whales are a dominant top-down force controlling herring populations in this region, at least for the two winters studied (2007-2008 and 2008-2009, Straley *et al.* 2018, Rice *et al.* 2011).

Kodiak

Research conducted as part of the GAP study indicates, that in the Kodiak region, humpback prey includes krill, capelin, juvenile pollock, sand lance, and smelt (see Table A3). Witteveen *et al.* (2012) examined 93 skin samples from humpback whales collected during summer feeding seasons from 2004 - 2006 and used stable isotope analysis (stable carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$)) with Bayesian mixing models to estimate the relative contributions of various prey in the diet. This study indicated that whales were feeding mainly on krill, but also capelin (> age 1 and age 1), juvenile pollock (age 0), and sand lance; and that relative proportions of these prey in the diet varied annually. Herring, eulachon, and age-1 pollock did not appear to be significant contributors to the diet in this region during the years of this study (Witteveen *et al.* 2012). Wright *et al.* (2016) applied the same techniques to examine

differences in diet composition between whales feeding at “North” and South” sub-regions of the eastern Kodiak Archipelago using skin samples collected during 2004 -2013 (n=55 “North” samples, n=63 “South” samples). Results indicated that krill was the dominant prey for whales in both sub-regions, but even more so for the whales in the “South.” Fish species were comparatively more important for whales in the “North,” where capelin, age-0 pollock, and sand lance (in order of decreasing contributions) also contributed to the diet (Wright *et al.* 2016). Sandfish, \geq age-3 eulachon, and $>$ age-1 herring were found to be the least important prey items (Wright *et al.* 2016). An older diet study conducted from 1937 - 1938 by Thompson (1940) analyzed stomachs from 39 whales off of Port Hobron, Kodiak. The stomachs mainly contained krill, but also surf smelt (*Hypomesus pretiosus*), an unidentified fish from the cod family (*gadidae*), and some copepods (but see Nemoto 1957).

Aleutian Islands and Bering Sea

In Aleutian and Bering Sea feeding areas, humpback whales forage mainly on krill but their prey are also known to include Atka mackerel, juvenile pollock, capelin, sand lance, and cod (see Table A4). Wynne and Witteveen (2013) observed whales foraging off of Shumagin Island and targeting dense schools of krill. Nemoto (1957, 1959) described the diet of humpback whales in this region based on the stomach content of whales caught by Japanese whaling vessels from 1952-1958 and found that stomachs (n = 392) contained krill or fish or both. Euphausiid species in humpback stomachs were mainly *T. inermis*, followed by *T. longipes*, *E. pacifica*, and *T. spinifera*. Nemoto (1957, 1959) noted that *E. pacifica* seemed to be a more dominant prey for whales taken in warmer North Pacific waters than whales taken north of the Aleutian Islands. Some stomachs contained copepod, *C. plumchrus*, but copepods are likely not an ordinary prey of humpback whales since these whales are usually distributed more near shore than copepods (according to Nemoto 1957, 1959). The fish contained in the humpback stomachs mainly included Atka mackerel, followed by capelin, sand lance, juvenile pollock, and cod (Nemoto 1957,1959). Based on analysis of an additional 458 humpback whale stomachs, Nemoto (1970) and Nemoto and Kawamura (1977) again found that euphausiids were the most common prey, with fish species also included in some stomachs (species not specified). Near Nunivak Island, whales were observed feeding on the euphausiid, *T. raschii* (Nemoto 1978). Further west, Thompson (1940) examined stomach contents of 14 whales captured in 1938 and 1939 off of Akutan in the Aleutian Islands and found only krill in the stomachs. Both west of Attu Island and South of Amchitka Island, Nemoto (1957) reported that humpback whales fed exclusively on Atka mackerel based on stomach contents of whales taken by Japanese whaling expeditions from 1953-1956.

Northern Bering Sea and Chukchi Sea

Klumov (1965) reports that humpback whales on the Russian side of the Bering Sea (near Commander Islands and South Kamchatka) were distributed near aggregations of spawning pollock. Humpback whales were also found near aggregations of capelin, herring, and Arctic cod in waters on the Russian side of the Bering Sea and Chukchi Sea (Klumov 1965). Klumov (1965) also reported a comprehensive list of humpback whale prey in the entire North Pacific based on available literature and “scanty material”

obtained during expeditions; and, in addition to the prey listed in other sources, prey items included on this list were mysids (*Mysis oculata*), *Calanus* copepod species, shrimp (*Pandalus goniurus*, *Eualus gaimardii*, and *Nephrops thomsonii*), tuna crab (*Pleuroncodes planipes*), Pacific lamprey (*Entospehnus tridentatus*), saury (*Cololabis saira*), Pacific cod (*Gadus macrocephalus*), saffron cod (*Eleginus gracilis*), pink salmon (*Oncorhynchus gorbuscha*), and northern rockfish (*Sebastes polyspinus*). Also, Tomilin (1967, as cited in Kawamura 1980) identified euphausiids (*Thysanoessa longipes*), mysids (*Mysis oculata*), shrimps (*Eualus gaimardii* and *Pandalus goniurus*), capelin, Arctic cod (*Boreogadus saida*), and saffron cod, in stomachs of humpback whales from this area. There is debate about the consumption of copepods in the North Pacific: Klumov (1965) listed copepods as part of humpback diet based prey noted in available literature, but Nemoto (1959) noted that copepods are unlikely to be targeted by humpback whales as prey given the distribution of humpback whales relative to copepods.

Diet Preferences

Based on the available data, humpback whales do not appear to have a preference between euphausiid species or life stages that occur within the feeding grounds of the North Pacific. Anecdotal observations of humpback whales associating with juvenile euphausiids in Southeast Alaska have been reported (Krieger and Wing 1986), but most studies don't specify the life stage of consumed euphausiids (Jurasz and Jurasz 1979, Krieger and Wing 1986). However, using net sampling and hydroacoustic data, Szabo (2011, 2015) concluded that humpback whales foraging during spring and summer in Southeast Alaska disproportionately targeted adult euphausiids over juveniles. Szabo (2011, 2015) also concluded that humpback whales do not discriminate among the four euphausiid species available in Southeast Alaska (e.g., *E. pacifica*, *T. raschii*, *T. longipes*, and *T. spinifera*). Although, as Szabo (2011) noted, the euphausiid species may not segregate sufficiently such that the whales could selectively target different species.

Relative consumption of krill versus small schooling fish by the whales is mainly a reflection of the relative density and abundance of the available prey as well as the oceanographic conditions or features that influence prey abundance. For example, based on stable isotope analyses of humpback whale diet over a 20-year period, Fleming *et al.* (2016) demonstrated that krill dominated humpback whale diet during positive phases of the North Pacific Gyre Oscillation (NPGO), with cool sea surface temperature, strong upwelling, and high krill biomass. Conversely, schooling fish dominated humpback whale diet during years characterized by negative NPGO shifts, delayed seasonal upwelling, and warmer temperatures (Fleming *et al.* 2016). Wright *et al.* (2015, 2016) found that the proportions of fish (mainly capelin as well as other fish) versus krill in humpback diet varied in different areas ("North" versus "South") around Kodiak Island based on stable isotope analysis and Bayesian modeling using skin samples from 118 whales taken from 2004-2013. This regional difference appeared to be related to the relative abundance of each prey in each region that likely varies due to oceanographic patterns (currents and topography/troughs). Similarly, humpback whales (n= 9) tagged during summers (2004 – 2011) in the Kodiak region targeted either fish or krill, depending on which prey occurred in highest densities (based on acoustic backscatter surveys) (Witteveen *et al.* 2015). In Prince William Sound, Moran and

Straley (2018) reported that diet shifted to mainly euphausiids in the summer, a time when adult herring biomass drops in the region. Within Southeast Alaska, in Sitka Sound, the number of whales eating herring increased as herring abundance increased, while the number of whales eating euphausiids decreased (Rice *et al.* 2011). However, in the same study, humpback whales feeding in Lynn Canal decreased as herring abundance increased, leading the authors to hypothesize the presence of a more preferred prey elsewhere or migration of whales out of the area to breeding areas (Rice *et al.* 2011).

Although not yet established, evidence suggests that humpback whales may preferentially target specific prey over another in order to maximize the energetic benefit. For example, capelin have a higher energy content than age-0 pollock (Anthony *et al.* 2000), and Witteveen *et al.* (2008) found that humpback whales may target capelin over juvenile pollock off of Kodiak, even when total density by weight is greater for pollock (although total density by number for capelin was greater). Wright *et al.* (2016) also found that capelin constituted a higher proportion of humpback whale diet than juvenile (age-0) pollock off of North Kodiak. Euphausiids generally have a lower energy content relative to fish (see Davis *et al.* 1998 and Anthony *et al.* 2000) and data from Witteveen *et al.* (2008) suggests that humpback whales were not targeting euphausiids near Kodiak even though euphausiids were likely present at the time of study based on acoustic data (backscatter was not confirmed to be euphausiids). However, other studies have found euphausiids to be the primary prey for humpback whales off Kodiak (Wright *et al.* 2016). Variation in fat content for prey species within Prince William Sound has been described by species as well as by season, with energy density (kJ/g) being greatest for fall adult herring, followed by summer juvenile herring, then fall sand lance, spring adult herring, fall krill, summer young of the year herring, summer young of the year pollock, and finally summer krill (Moran and Straley 2018). Fat content of older, pre-spawning Pacific herring also varies by season, with the lowest fat content in spring and highest in summer/fall (Iverson *et al.* 2002, Moran and Straley 2018). Although other prey are present within the system (including euphausiids), humpback whale distributions in Prince William Sound are typically associated with dense shoals of herring, and the whales have been observed following energy-rich adult herring as the fish move to their spawning grounds in fall/winter and spring (Moran and Straley 2018).

Energy Requirements

Because humpback whales only rarely feed on breeding grounds and during migrations, the buildup of fat stores while on the feeding grounds is critical to support migration and successful breeding. Given the energetic costs associated with foraging activity itself, especially at deeper depths (Goldbogen *et al.* 2008), foraging is only expected to be profitable above some lower threshold for an energetic return. Evidence suggests that humpback whales will feed when they encounter suitable concentrations of prey. Although humpback whales have often been observed in association with, or specifically targeting, dense aggregations of prey within North Pacific feeding regions (e.g., Bryant *et al.* 1981, Krieger and Wing 1986, Goldbogen *et al.* 2008, Sigler *et al.* 2012, Witteveen *et al.* 2015), prey densities required to support feeding are not generally known. Burrows *et al.* (2016) found a significant relationship between

humpback whale lunge frequency and krill density for six whales in Sitka Sound, Alaska, showing that humpback whales tended to feed where krill were most concentrated within the water column. These authors opportunistically sampled krill density at the scale of an individual whale, which had just ceased foraging, and estimated the krill density around the feeding whale to be 9,434 krill m^{-3} based on acoustic data. It was not possible to determine whether krill density or some other factor (satiated, tired, etc.) caused the particular whale to stop feeding (Burrows *et al.* 2016). Based on diving behavior of tagged whales and analysis of underwater video of prey aggregations in Frederick Sound, Alaska, Dolphin (1987) concluded that the minimum density of krill that humpback whales would feed on was 50 krill m^{-3} , although more typically humpback whales fed on densities of krill ranging from 3,000-10,000 euphausiids m^{-3} .

Energy requirements vary by life stage for humpback whales. Of all life stages, lactating females have the greatest energy demand, followed by other adult females (pregnant, then resting; McMillan 2014). Body condition of all mature whales and lactating females also decreases throughout the breeding season (more so than immatures and calves), with a greater decline rate for lactating females (Christiansen *et al.* 2016). Therefore, pregnant females in the preceding feeding season likely have large energy requirements to build up stores before lactating. A study of minke whales, which are within the same family as humpback whales, showed that mature and pregnant females had greater increases in blubber volume than other reproductive classes during the feeding season, indicating their greater build-up of energy stores (Christiansen *et al.* 2013). McMillan (2014) calculated yearly energy requirements for humpback whales at different life stages off of British Columbia (Table 2). Based on these values, if whales were to consume only herring, each whale would need to consume between 92.6 t to 217.5 t per year, depending on the whale's life stage.

Several studies have estimated total prey consumption by humpback whales in a year within a region based on approximate diets, energy needs, and humpback abundance. For an estimated 942 humpback whales feeding off the U.S. West Coast (based on mean summer and fall abundance from 1991-2005), Barlow *et al.* (2008) used three consumption models to calculate that between 110,106 to 157,735 t of prey would be consumed annually. For these models, the authors assumed that 83% of the humpback whale annual diet was consumed within the U.S. CCE and that 55% of the humpback diet was "large zooplankton", 15% "small pelagic fish", and 30% "miscellaneous fish" (Barlow *et al.* 2008, approximate diet from Pauly *et al.* 1998). Since that study, humpback whale abundance in the CCE may have doubled (Barlow 2016), which would result in a doubling of the estimated prey consumption. Using an average body mass of 30,408 kg and a diet reflecting the relative occurrences of prey (as determined by mid-water trawl surveys) off northeastern Kodiak Island, Witteveen *et al.* (2006) estimated that the whales would need to consume 370 kg/day. The estimated 157 humpback whales in the study area (95% CI=114-241), were estimated to consume 8.8×10^6 kg annually within a five month feeding season. This equated to a total of 3.26×10^6 kg of pollock, close to 2.55×10^6 kg capelin, and 6.71×10^5 kg of eulachon, assuming that the actual diet corresponded to the estimated relative prey availability in the

area. Using a pre-whaling abundance estimate of 343 whales, Witteveen *et al.* (2006) also estimated that, if this particular humpback whale feeding aggregation returned to pre-whaling abundance levels, they would consume 1.9×10^7 kg of prey annually, an order of magnitude greater.

Table 2. Average yearly energy requirements by life stage and sex for humpback whales feeding on herring off of British Columbia. Values from McMillan (2014).

Life stage/Sex	Energy requirement (average)
Lactating females	1.66×10^6 MJ year ⁻¹
Pregnant females	1.06×10^6 MJ year ⁻¹
Resting females	1.02×10^6 MJ year ⁻¹
Adult males	7.35×10^5 MJ year ⁻¹
Juvenile females	8.78×10^5 MJ year ⁻¹
Juvenile males	6.45×10^5 MJ year ⁻¹
Female calves	5.15×10^5 MJ year ⁻¹
Male calves	4.30×10^5 MJ year ⁻¹

Foraging Strategies

Humpback whales are gulp feeders, gulping mouthfuls of prey and water when feeding (Ingebrigtsen 1929), and use a variety of capture techniques, including lunges and bubble structures (bubble nets, columns, clouds, and curtains; Jurasz and Jurasz 1979, Hain *et al.* 1982). In general, humpback whales will lunge feed, both towards the surface and at depths, while alternating between periods of short, shallow dives and long, deeper dives, and can execute multiple lunges in one dive (Goldbogen *et al.* 2008). Lunge types include lateral lunge feeding, vertical lunge feeding, and inverted lunge feeding (Jurasz and Jurasz 1979). Additionally, humpbacks have been observed using multiple types of bubble structure feeding techniques for capturing prey, such as bubble nets, columns, clouds, and curtains (Jurasz and Jurasz 1979, Hain *et al.* 1982), and techniques that combine clouds with surface disturbances (like lobtail feeding, Weinrich *et al.* 1992). Artificial bubble structures have been shown experimentally to constrain the spatial movement of herring, particularly large schools (Sharpe and Dill 1997), supporting the conclusion that bubble techniques are likely an effective method for herding prey.

Other techniques may be used to aid in herding prey. Termed “blaze feeding,” whales have been documented to flash the white side of their pectoral flipper at prey, possibly in an effort to herd prey towards their mouths (which likely appears as a black “open” area between the white pectoral flippers) (Tomilin 1957 cited in Brodie 1977, Sharpe 2001). Work by Sharpe (2001) with artificial flippers supported this hypothesis, as herring would flee from the long axis of an artificial flipper, towards where a whale’s mouth would be. Trap-feeding is recently described feeding technique observed being used by whales feeding off Vancouver Island, Canada as a strategy for feeding on fish prey that are more diffuse or present in lower densities (McMillan *et al.* 2019). To trap-feed, an individual whale remains fairly stationary just below the surface and hold its mouth open to allow the fish prey to accumulate in its mouth or “trap;” and, it may sometimes use its pectoral fins to help push the prey towards its mouth (McMillan *et al.* 2019). Additional feeding strategies that have been documented include, swimming/thrashing (roiling the surface and thrashing tail, Hain *et al.* 1982), looping, flick feeding (lashing tail at the surface, Jurasz and Jurasz 1979), vertical rise and subsidence (creates a reduced pressure zone in the water column, Hays *et al.* 1985), and “roiling” the surface with flippers and flukes (Hain *et al.* 1982).

Different feeding techniques are likely associated with different prey, prey densities (as noted above for trap-feeding), or even prey behavior. Off of Maine, humpback whales were observed bottom feeding at night, probably in response to the diel vertical migration and burrowing of sand lance prey (Friedlaender *et al.* 2009). Whales would repeatedly roll near the bottom, likely in order to stir-up the sand-lance. Conversely, Szesciorka (2015) documented shallower dives for humpback whales at night off of California, possibly related to the upward diel vertical migration of prey there.

Humpback whales may also work in groups to herd and capture prey and can use vocalizations to coordinate this effort (see “Vocalization and Sound,” below). In Southeast Alaska, groups of whales have been observed to release bubbles simultaneously in the same area, and then surface through the center together to consume the herded herring (Jurasz and Jurasz 1979, Baker 1985, D’Vincent *et al.* 1985). Vocalizations seem to be important in coordinating these group feeding efforts (D’Vincent *et al.* 1985, see “Sound and Vocalization”).

Dive depth of foraging humpback whales varies by prey species, but it is likely not energy efficient for humpback whales to access prey at all depths. In Alaska, Witteveen *et al.* (2015) reported that whales dove deeper to forage on krill than on fish (average depths of 98 m versus 80 m, respectively). Similarly, in areas off of California, Szesciorka (2015) documented shallower feeding on the continental shelf where fish were more readily available, and deeper feeding on continental break/slope where krill were present. For dive depths in general, multiple authors have documented varying average and maximum dive depths, with mean depths ranging from around 66 m to 107 m and maximum depths ranging from approximately 115 m to 388 m (in Alaska, California, and Antarctica; Witteveen *et al.* 2008, Simon *et al.* 2012, Tyson 2014, Szesciorka 2015, Witteveen *et al.* 2015). For humpback whales off of Antarctica, Friedlaender *et al.* (2016) found that whales would not feed when krill were in deep, high density patches but began to feed when krill migrated to the surface and formed larger, less dense patches. Goldbogen *et al.* (2008), also found that humpback whales tend to feed at the upper most section of

high density krill patches. Foraging on prey closer to the surface likely minimizes energy costs from diving and searching (Friedlaender *et al.* 2016).

Mothers will adjust diving duration when with calves. Szabo and Duffus (2008) followed 42 humpback mother-calf pairs off of Alaska and found that compared to their mothers, calves dive less often and for shorter durations. Mothers would then also shorten their dive duration (compared to other whales) to minimize separation time from their calf (and therefore reduce the potential for predation). As the calves got older, mothers shortened their dives less and calves increased their participation in synchronizing dives in order to stay near their mothers.

How baleen whales detect prey is not well understood (Tyack 1997). Unlike odontocetes that use echolocation, humpback whales may use other senses to locate prey. Findings in Friedlaender *et al.* (2009) suggest that humpback whales may largely rely on visual detection of their prey when surface feeding. It has also been hypothesized that the whales use the hairs, located in the large, innervated bumps called tubercles on their head, to mechanically sense prey or changes in prey density (see Ogawa and Shida 1950; Slijper 1979). Sound may also be used by humpback whales to detect prey (see also “Vocalizations and Sound” below). For instance, Pacific herring produce distinctive, broadband sounds (1.7 – 22 kHz; Wilson *et al.* 2004), and it is possible that these sounds could inadvertently cue the whales. Yi and Makris (2016) determined that humpback whales are physically capable of acoustically detecting herring schools within a 10 km (+/- 6 km) distance. However, this study did not examine whether humpback whales actively sense prey using sound, only at what distances this might be feasible. In addition, it has been proposed that humpback whales may use a form of echolocation to detect patches of prey. Specifically, whales foraging at night in Massachusetts Bay have also been observed producing “megapclicks,” which are sounds with characteristics similar to those of odontocete clicks and may represent a form of echolocation (Stimpert *et al.* 2007). However, the megapclicks may be used for herding prey rather than locating prey (Stimpert *et al.* 2007).

Recently published research provides evidence that humpback whales can use chemical cues to sense their prey over several hundred meters. Behavioral experiments were used to test humpback whales’ reactions to two chemical cues, specifically krill extract and dimethyl sulfide (DMS), which is a chemical released in areas of high marine productivity (Bouchard *et al.* 2019). Relative to control cues (orange clay and vegetable oil), Bouchard *et al.* (2019) found that the whales spent significantly longer amounts of time in the krill extract zone relative to control zones at two of the three study locations (Madagascar and Iceland; with the third being Antarctica). No response was detected for experiments conducted with the DMS extract at any of the sites.

Vocalizations and Sound

Like most cetacean species, humpback whales rely extensively on sound for communication and sensing their environment. Broadly speaking, the production of sound among humpback whales can be grouped into three behavioral contexts: song, social sounds, and feeding calls. The song, produced only by male humpback whales, was first described by Payne and McVay (1971) and is generally thought to function

as a display of fitness towards other males, females, or both (Darling and Bérubé, 2001, Parsons *et al.* 2008, Smith *et al.* 2008, Herman 2016), although other functions have also been proposed (Herman and Tavolga 1980, Frankel *et al.* 1995, Frazer and Mercado 2000). The song is hierarchically structured, whereby individual song “units” are ordered into distinct “phrases,” multiple phrases are organized into a “theme” and several themes make up the song, the production of which can last up to 20 minutes. Song is produced primarily on the wintertime breeding grounds, but is also often recorded along migration routes (Norris *et al.* 1999, Noad and Cato 2007). Singing has also been reported from some feeding areas in the North Atlantic and Antarctic; and while multiple hypotheses have been put forth to explain the cause and purpose of this “off season” singing, the biological role and significance of singing in the feeding areas remains unclear (Clark and Clapham 2004, Stimpert *et al.* 2012, Magnúsdóttir *et al.* 2014). Song units range in frequency between approximately 50 Hz and 3 kHz, although tonal harmonics can extend beyond 24 kHz (Au *et al.* 2006). As a result, there has been speculation that humpback whales may hear frequencies as high as 24 kHz (Au *et al.* 2006), but empirical hearing evidence is lacking to support or refute this hypothesis. Male humpback whales on a breeding ground all sing approximately the same song but that song changes over the course of a breeding season and between seasons. Humpback whale song is considered evidence of cultural transmission in the species, supported in part by the transfer of song properties across populations (Garland *et al.* 2011).

In contrast to the structured nature of song, social sounds are isolated vocalizations or short sequences of largely unstructured sounds. Included among these are often non-vocal sounds produced during surface-active behaviors such as breaches and tail slaps (Dunlop *et al.* 2013). These sounds are not confined to males and are produced by females as well as calves (Dunlop *et al.* 2008, Zoidis *et al.* 2008) under a variety of social and behavioral contexts (Dunlop *et al.* 2008, Dunlop *et al.* 2010). Social sounds are not produced only seasonally, like song, and they are commonly recorded on the feeding grounds (Thompson *et al.* 1986, Stimpert *et al.* 2011), the breeding grounds (Silber 1986, Zoidis *et al.* 2008), and on migration routes (Dunlop *et al.* 2007, 2013). The properties of many vocal social sounds are similar in frequency and duration to song units, but without being produced in patterned sequences. Most vocal social sounds have peak frequencies below 1 kHz, but can range as high as 6 kHz (Stimpert *et al.* 2011). The communicative function of these sounds remains unclear, but certain sounds have been suggested to function as signals communicating motivational state (e.g. aggression, fear, arousal) among individuals (Dunlop 2017), as contact calls between mothers and calves (Zoidis *et al.* 2008), and as long-range signaling cues among dispersed individuals in the case of non-vocal sounds produced during surface activity (Kavanagh *et al.* 2017)). A recent study compared non-song vocalizations of humpback whales in Alaska between the 1970s and more recently (2012), and found that the majority of call types have persisted and all call types were heard in at least three of the four decades studied, showing that these calls are highly stable over generations (Fournet *et al.* 2018).

The third behavioral context associated with sound production is feeding. Several studies have documented the use of sounds by foraging humpback whales. These sounds vary by feeding context and location. D'Vincent *et al.* (1985) described whales feeding on schools of krill and herring in Southeast

Alaska while producing extended bouts of tonal sounds centered around 500 Hz. These sounds are typically associated with coordinated lunge feeding, often involving bubble nets used to concentrate the prey. There is also evidence that humpback whales produce cries specific to individuals, and this is hypothesized to aid in herding prey (Cerchio and Dahlheim 2001). As noted earlier, another type of sound called the “megapclick” was described for whales foraging at night in Massachusetts Bay (Stimpert *et al.* 2007). Characteristics of megapclicks, including a terminal buzz sequence, resemble those of odontocete clicks, which led to speculation that they might represent a form of echolocation. However, this was deemed doubtful, and a prey herding function has been put forth as an alternative explanation (possibly for herring, although the prey species were not confirmed; Stimpert *et al.* 2007). Bottom-feeding humpback whales from the same region were also shown to produce another type of sound, termed the “paired burst” (Parks *et al.* 2014). This sound was tied specifically to whales feeding on bottom prey, most likely sand lance, which burrow into the sediment. It was concluded that these paired burst sounds likely function either to manipulate prey behavior, to communicate with conspecifics, or some combination of these two functions. Additionally, multiple studies in the Gulf of Maine have found evidence that humpback whale vocalization levels, including song-like vocalizations, are spatially and temporally correlated with high density aggregations of spawning herring (Gong *et al.* 2014, Huang *et al.* 2016, Wang *et al.* 2016).

Observed responses of prey to humpback whale sounds further supports that sound is used as a herding mechanism. Using recorded vocalizations of humpback whales, Sharpe (2001) showed that herring (prey), in the lab and in the wild, will move away from humpback vocalizations and form denser schools (with smaller distances between individuals). This aggregates herring for foraging whales and may further facilitate foraging if herring flee towards the surface, allowing for bubble net/cloud capture. It has also been hypothesized that humpback whales may benefit from sounds of other marine mammals. For example, it has been hypothesized that humpback whales may be attracted to aggregations of fish prey by sounds produced by fish-eating ecotypes of killer whale (Jourdain and Vangraven 2017).

Predators and Sound

Killer whales are considered the most common predator of humpback whales, calves in particular (Fleming and Jackson 2011). Predation by large sharks may also occur, and some rare attacks by false killer whales (*Pseudorca crassidens*) have also been reported or suggested (Fleming and Jackson 2011). Predation by killer whales has rarely been witnessed and is not considered to be a significant threat to humpback whale populations (Bettridge *et al.* 2015), but substantial scarring has been noted on many humpback whales and is thought to be due to killer whales (Shevchenko 1975, Steiger *et al.* 2008). In one particular study conducted off Western Australia, killer whales were observed over a period of 6 days attacking eight humpback whale calves, resulting in at least three mortalities (Pitman *et al.* 2015). Evidence also suggests that humpback whales typically will vigorously defend themselves, especially mother-calf pairs, from killer whales and other predators (Ford and Reeves 2008, Pitman *et al.* 2015).

Some research suggests that sound may play a role in how humpback whales respond to killer whales. In one study in the Atlantic, eight humpback whales were played killer whale noises and were observed to cease feeding, change direction, and travel steadily away from the sound (Curé *et al.* 2015). Mother-calf pairs were also observed to alternate between swimming rapidly away from the killer whale sounds and

making 90 degree turns, possibly in an attempt to avoid or confuse the predator (Cure *et al.* 2015). Additionally, Sivle *et al.* (2015) exposed 11 tagged humpback whales to multiple, experimental sound treatments (sonar, no sonar controls, killer whale playbacks, and broadband noise controls), and found that changes in behavior were more severe in response to sonar and killer whale sounds relative to the control treatments. Humpback whales responded to killer whale sounds by avoiding the sound source, changing their dive pattern, or ceasing to feed (Silve *et al.* 2015).

For mother-calf pairs, vocalizations may be an important mechanism for maintaining their close association; however, such signals may have the unintended consequence of attracting killer whale predators (Videsen *et al.* 2017). To minimize detection by predators (as well as disruptive humpback male escorts), mother-calf pairs may use non-acoustic mechanical cues or weak calls (e.g., grunts or tonal sounds) requiring close communication space (e.g., < 100m, Videsen *et al.* 2017). Sufficient evidence, however, is not yet available to confirm this hypothesis.

Geographical Range Occupied by the Species

Mexico DPS

The Mexico DPS of humpback whales is defined in 50 CFR 223.102(e) as those humpback whales that breed or winter in the area of mainland Mexico and the Revillagigedo Islands, transit Baja California, or feed in the North Pacific Ocean, primarily off California-Oregon, northern Washington/southern British Columbia, northern and western Gulf of Alaska, and East Bering Sea.

Within U.S. waters, the range occupied by the Mexico humpback whale DPS at the time of listing has been derived from photo-identification data and genetic data and, in particular, from results of the SPLASH study. As noted earlier, the SPLASH study involved the collection of both photographic and genetic data by several hundred researchers working in over 10 countries (Calambokidis *et al.* 2008). Photo-identification data were collected over three breeding seasons (2004, 2005, and 2006) and over two feeding seasons (2004, 2005) in six breeding regions and six feeding regions (Figure 3). Across all sampling seasons, whales that were photo-identified in the wintering/breeding areas for this DPS (i.e., Mexico mainland, Baja California, and the Revillagigedo Islands, n=1,868 distinct photo-identified whales) were matched to whales in all five of the major feeding areas in, or partially in, U.S. waters - California/Oregon (n=105 whales), northern Washington/southern British Columbia (n=27 whales), southeast Alaska/ northern British Columbia (n=35 whales), the Gulf of Alaska (between Yakutat and Alaska Peninsula, n=97 whales), and the Aleutian Islands/ Bering Sea (n=27 whales, Barlow *et al.* 2011; Figure 13). This DPS has also been documented within the Salish Sea (Calambokidis *et al.* 2017). Sightings of humpback whales in general have increased dramatically in the Salish Sea from 1995 to 2015, and at least 11 whales from this DPS have been matched to those sighted within this area (Calambokidis *et al.* 2017). Overall, the available data demonstrate that the Mexico DPS is broadly distributed within U.S. waters.

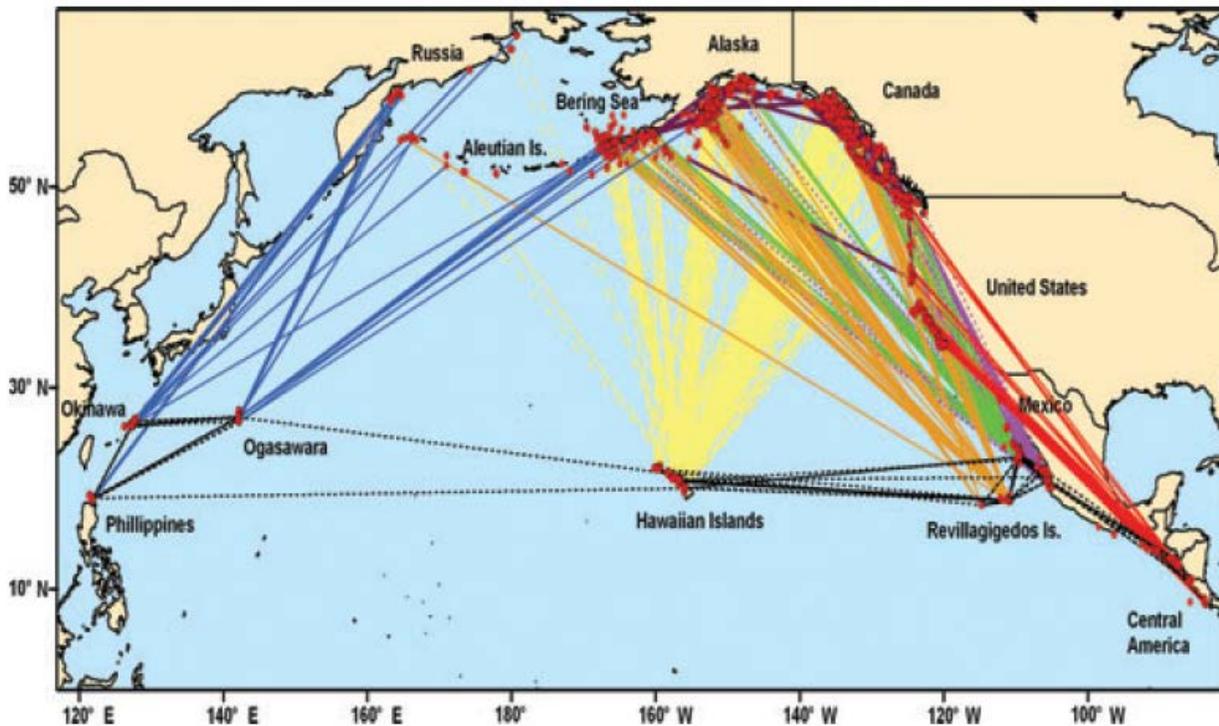


Figure 13. Locations of photo-identified whales (red dots) observed during the SPLASH study. Matches of identified whales between foraging areas and breeding areas across all seasons of the study (2004-2006) are depicted by colored lines. However, black dotted lines indicate matches between breeding areas and dark purple lines indicate matches between foraging areas. Lines do not indicate migration routes. The listed DPSs are indicated by colored lines as follows: blue - Western North Pacific DPS, orange and green - Mexico DPS, red - Central America DPS. Non-listed whales from Hawaii breeding areas are indicated by the yellow lines. Figure from Barlow *et al.* (2011).

In terms of distribution across this range, whales from this DPS, and specifically those whales photo-identified along the Pacific coast of mainland Mexico, were sighted in highest numbers during the SPLASH surveys off the coast of California and Oregon (97 of 164 total matches), suggesting that this is their primary foraging destination (Calambokidis *et al.* 2008, Barlow *et al.* 2011). This finding is consistent with the pattern observed in an earlier photo-identification study conducted from 1990-1993 in which 48 of 58 re-sighted whales initially identified off the coast of Mexico (predominately off the mainland) were sighted in California (Calambokidis *et al.* 2001). In this same study, the remaining re-sightings within the feeding areas occurred off northern and southern British Columbia, Prince William Sound, and Kodiak and eastern Aleutian Islands, which again indicates a broad distribution across the known North Pacific feeding areas (Calambokidis *et al.* 2001). Results of the SPLASH study indicate that although whales sighted off mainland Mexico also travel to the more northern latitude feeding areas, the whales sighted around the Revillagigedo Archipelago had more matches overall to Alaska feeding

areas and had higher match rates to the northern Gulf of Alaska feeding area in particular (44 of 87 matches; Calambokidis *et al.* 2008).

Genetic data collected during the SPLASH study indicated population structure patterns that are consistent with previous genetic studies (e.g., Palumbi and Baker 1994, Baker *et al.* 1998) and consistent with some of the patterns indicated by the photo-identification data; and overall, lend support to our understanding of the range occupied by this DPS. In particular, pairwise comparisons of mitochondrial DNA (mtDNA) haplotypes (using F_{ST} values) indicated there were no significant differences (at $p < 0.05$, 0.01, or 0.001) between whales sampled from any of the breeding/wintering areas of this DPS (i.e., mainland Mexico ($n= 62$), Revillagigedo ($n= 106$), and Baja California ($n= 110$) and whales sampled in the western Gulf of Alaska ($n= 96$) or whales sampled in the eastern Aleutians ($n=36$, F_{ST} values ranged from 0 - 0.011, Baker *et al.* 2013). Significant differences in mtDNA haplotypes were also not detected between whales from the mainland Mexico breeding area ($n= 62$) and the Bering Sea ($n=114$, $F_{ST} = 0.013$, Baker *et al.* 2013). The genetic similarity of these whales provides strong evidence that Mexico DPS whales, in particular females of this DPS, migrate to these particular foraging areas. Interestingly, however, whales sampled from each of the three wintering/breeding areas for the Mexico DPS whales, had significantly differentiated ($F_{ST} = 0.045- 0.066$, $p < 0.001$) mtDNA haplotypes from whales sampled in the California/Oregon feeding area ($n= 123$) despite the large amount of photo-identification evidence that the whales migrate between these areas (Baker *et al.* 2013, Calambokidis *et al.* 2001 and 2008). This result is likely driven by the mixing of whales from other populations, including whales from the Central America DPS, within this particular feeding ground as evidenced by photo-identification data (Barlow *et al.* 2011).

North of the Bering Strait, the range of this DPS is not yet resolved. Results of aerial surveys in the late 1970s and oceanographic surveys in the 1970s and 1980s in the northeastern Chukchi and western Beaufort Seas resulted in few sightings of humpback whales in U.S. waters; and later surveys in 2007, 2008, and 2012 resulted in only scattered sightings (reviewed in Clarke *et al.* 2013). However, more recent aerial, vessel, and acoustic surveys conducted in the southern Chukchi Sea during 2009 to 2012 indicate that humpback whales occur fairly commonly and widely within this particular region, including east of the International Date Line (Clarke *et al.* 2013, Figure 14). However, photo-identification or genetic data are not yet available to connect the humpback whales observed in the southern Chukchi Sea to a particular DPS. We are also lacking such data for humpback whales in the northeastern Chukchi and western Beaufort Seas. Therefore, we cannot yet describe with precision the northern extent of the range for the Mexico DPS.

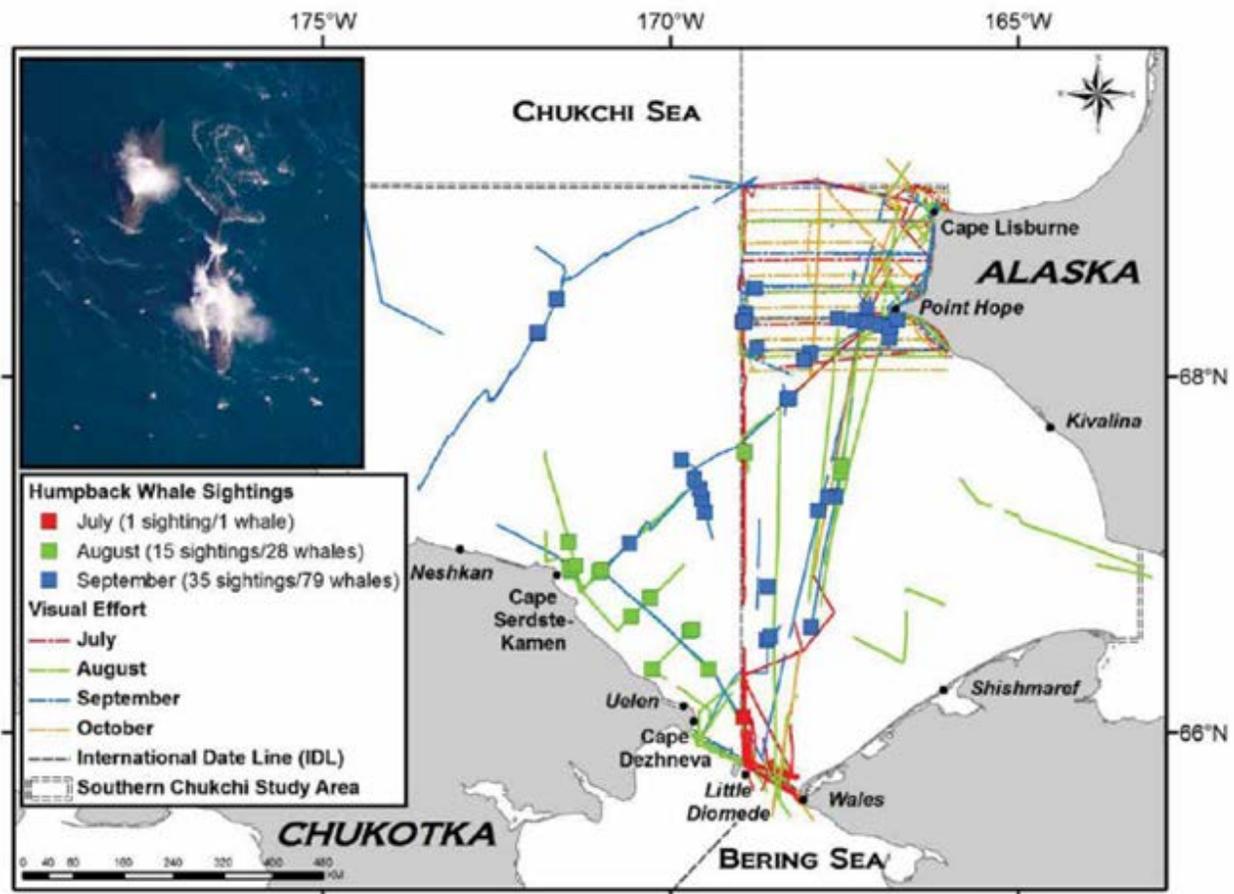


Figure 14. Sightings of humpback whales by month during aerial (dotted lines) and vessel (solid lines) surveys conducted in the southern Chukchi Sea from July to October 2009 – 2012. The inset photo shows humpback whales observed near Point Hope, Alaska. Figure from Clarke *et al.* (2013).

Central America DPS

The Central America DPS is defined as those humpback whales that breed in waters off Central America in the North Pacific Ocean and feed along the west coast of the United States and southern British Columbia (50 CFR 224.101(h)). The breeding range of this DPS includes waters off the Pacific coast of Central America, from Panama north to Guatemala, and possibly into southern Mexico (Bettridge *et al.* 2015, Calambokidis *et al.* 2017). Whales from this DPS have been observed within foraging grounds along the coasts of California, Oregon, and Washington (Barlow *et al.* 2011).

In terms of distribution across their foraging range, these whales are significantly more common in waters of southern California and occur in increasingly lower numbers off the coast of Washington and Southern British Columbia (Steiger *et al.* 1991; Rasmussen *et al.* 2001; Calambokidis *et al.* 2000, 2008, 2017). Of the humpback whales identified off the coast of Central America (n=31) in a photo-

identification study conducted between 1981 and 1992, 84% were re-sighted off California (Calambokidis *et al.* 2000). This distribution pattern was also confirmed by the results of the SPLASH study, which indicated that out of 29 between-season photo-identification matches of whales from the Central America breeding areas, 26 occurred within the California/ Oregon feeding area and 3 occurred within the northern Washington/ southern British Columbia area (Barlow *et al.* 2011). Use of the Salish Sea by this DPS may be extremely limited, and has been indicated by the single re-sighting reported in Calambokidis *et al.* (2017), and no observations of these whales have been reported for waters off Alaska or in the Bering Sea.

Genetic data collected during the SPLASH further support the range and distribution patterns indicated by the photo-identification studies. Specifically, the Central American (n=36) samples showed no differentiation in mtDNA haplotypes (F_{ST}) from the California/Oregon samples (n=123, Baker *et al.* 2013).

Western North Pacific DPS

Humpback whales of this DPS are those that breed or winter in the area of Okinawa and the Philippines in the Kuroshio Current (as well as unknown breeding grounds in the Western North Pacific Ocean), transit the Ogasawara area, or feed in the North Pacific Ocean, primarily in the West Bering Sea and off the Russian coast and the Aleutian Islands (50 CFR 224.101(h)). As indicated by the regulatory definition of this DPS, the breeding range of the Western Pacific DPS has not yet been fully resolved; however, at the time of listing the breeding range was established as including the waters off Okinawa and the Philippines in the area of the Babuyan Islands (Barlow *et al.* 2011, Bettridge *et al.* 2015, Wade *et al.* 2016). Whales from this DPS have been sighted in foraging areas off the coast of Russia, primarily Kamchatka, the Aleutian Islands, as well as in the Bering Sea and Gulf of Alaska, and off British Columbia (Figure 13; Darling *et al.* 1996, Calambokidis *et al.* 2001, Barlow *et al.* 2011). Some whales from this DPS are thought to migrate through waters off Ogasawara when transiting between seasonal habitats (Bettridge *et al.* 2015). Whales from this DPS have not been observed in the foraging areas off Washington, Oregon, and California. A single whale has also been photo-identified in both Japan (off the Ogasawara archipelago in April of 1990) and then later Hawaii, with the sightings occurring 10 months apart (Darling and Cerchio 1993).

Humpback whales have been infrequently sighted near the Mariana Islands, mainly off of Saipan (Fulling *et al.* 2011, Hill *et al.* 2016, 2017), and although unconfirmed, it is possible that these sightings correspond to an additional breeding ground for the Western North Pacific DPS. In addition to sightings, humpback whale song has been acoustically detected in this area (Fulling *et al.* 2011). A few researchers have suggested that these observations point to there being a small wintering population of whales that migrate through the area (Fulling *et al.* 2011, Ligon *et al.* 2011). Specifically, Ligon *et al.* (2011) noted that whales sighted did not linger near the main islands, suggesting that the whales were “traveling.” Although no humpback whales were sighted in this area between 2009-2014 (Fulling *et al.* 2011, Hill *et al.* 2014, Ligon *et al.* 2013), in February and March of 2015, four mother/calf pairs and four humpback whale individuals were spotted off of Saipan (Hill *et al.* 2016). The calves were young of the year (YOY), suggesting that the Mariana Islands may serve as breeding and calving habitat. In 2016, four mother-calf

pairs were seen, including one mother that was seen previously in 2007 and one neonate, again suggesting the area is a calving area (Hill *et al.* 2017). In 2017 surveys, two mother calf pairs were observed out of 13 total humpback whale encounters, which included sightings of three adults seen previously in the area (Hill *et al.* 2018). To date, a total of 41 unique individuals have been photo-identified and catalogued; and between 2007 and 2018, seven of these whales were re-sighted off Saipan (Hill *et al.* 2019, in review).

Photo-identification data for humpback whales sampled off Saipan in 2015–2018 suggest that whales sampled in this area belong to the Western North Pacific DPS (Hill *et al.* in review). Comparisons with existing Western North Pacific humpback whale photo-identification catalogs found that 11 of 41 (27%) whales within the Mariana Archipelago humpback whale catalog were previously sighted in Western North Pacific breeding areas (Japan and Philippines) and/or feeding area off Russia (Hill *et al.* in review). Analysis of mtDNA haplotype frequencies for whales biopsied off Saipan indicate that the whales genotyped (n=24) are significantly differentiated ($p < 0.05$) from humpback whales from some Western North Pacific breeding areas (Philippines and Okinawa) but are not significantly differentiated from whales from the Ogasawara area (Hill *et al.* in review). The Saipan whales were also not significantly differentiated from humpback whales sampled in Russia feeding areas nor in any of the three Mexico breeding areas (Hill *et al.*, in review). Overall, the available genetic analyses do not definitively align the whales to the WNP DPS.

Sightings and acoustic detections indicate that humpback whales occur off of the Northwest Hawaiian Islands (NWHI) during winter months (Johnston *et al.* 2007, Lammers *et al.* 2011). Observations of behaviors consistent with breeding (e.g. song) and spatial analysis of habitat variables (water temperature, depth) and whale distributions suggest this area serves as breeding habitat; however, further research is required to confirm this (Johnston *et al.* 2007). Although this area is another candidate for the as yet unidentified breeding area for the Western North Pacific DPS, a more parsimonious explanation is that these whales belong to the Hawaii DPS.

Within U.S. waters, Western North Pacific DPS whales are most likely to be found off the Aleutian Islands and in the Bering Sea (Wade *et al.* 2016, Wade 2017). Although limited in number, photo-identified whales from the breeding areas of this DPS have been sighted in the Kodiak (Calambokidis *et al.* 2001 and 2008) and Shumagin Island regions of Alaska (Witteveen *et al.* 2004). During the SPLASH study (2004-2006), photo-identified individuals from this DPS were matched to the Gulf of Alaska (n=2), the Aleutian Islands/Bering Sea (n=9), and Kamchatka foraging area (n=21, Barlow *et al.* 2011; Figure 13).

As noted above for the Mexico DPS of humpbacks, the northern extent of the range of this DPS is not yet resolved. Sightings and acoustic detections of humpback whales in the southern Chukchi Sea during 2009 to 2012 indicate that humpback whales occur fairly commonly and widely within this particular region, including east of the International Date Line (Clarke *et al.* 2013, Figure 14). Photo-identification or genetic data are not yet available to connect the humpback whales observed in the southern Chukchi Sea to a particular DPS. We are also lacking such data for humpback whales in the northeastern Chukchi

and western Beaufort Seas. Therefore, we cannot yet describe with precision the northern extent of the range for the Western North Pacific DPS.

Essential Physical and Biological Features

As discussed previously, occupied critical habitat is statutorily defined as those areas “on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection” (16 U.S.C. 1532 (5)(A)). The ESA does not specifically define physical or biological features; however, joint NMFS-USFWS regulations at 50 CFR 424.02 (84 FR 45020, August 27, 2019) provide guidance on how physical or biological features are expressed. Specifically, these implementing regulations define “physical or biological features essential to the conservation of the species” as follows:

The features that occur in specific areas and that are essential to support the life-history needs of the species, including but not limited to, water characteristics, soil type, geological features, sites, prey, vegetation, symbiotic species, or other features. A feature may be a single habitat characteristic, or a more complex combination of habitat characteristics. Features may include habitat characteristics that support ephemeral or dynamic habitat conditions. Features may also be expressed in terms relating to principles of conservation biology, such as patch size, distribution distances, and connectivity.

To assess habitat features that may qualify as “essential to the conservation” of humpback whales, the CHRT discussed physical and biological features necessary to support the life history needs and support the conservation of the whales within the areas they occupy within U.S. waters. The CHRT considered and evaluated features of humpback whale habitat, including (but not limited to) prey, migratory corridors or conditions, and sound. Significant considerations, CHRT discussions, and resulting conclusions are provided below.

Prey as an Essential Feature

Based on a review of the best available scientific data, the CHRT unanimously concluded that prey within humpback whale feeding areas are essential to the conservation of each of the three DPSs of humpback whales. This feature is defined as follows:

Prey species, primarily euphausiids and small pelagic schooling fishes of sufficient quality, abundance, and accessibility within humpback whale feeding areas to support feeding and population growth.

Although written for the taxonomic species and thus technically now outdated, the 1991 NMFS Recovery Plan for humpback whales, identified four major recovery objectives, the first of which was, “maintain and enhance habitats used by humpback whales currently or historically” (NMFS, 1991). As part of that objective, NMFS identified multiple actions, including “providing adequate nutrition” and

“monitoring levels of prey abundance” (NMFS 1991). The Recovery Plan states that adequate nutrition is needed for the recovery of the species, and emphasized the need to maintain and optimize levels of, and access to, prey (NMFS 1991). The Recovery Plan also noted that humpback whales require access to prey over a sufficiently widespread feeding range to buffer them from local fluctuations in productivity or fisheries removals (NMFS 1991). As we discuss here, this recovery objective and the related actions regarding adequate nutrition and prey abundance and availability are still relevant today for the Mexico, Central America, and Western North Pacific DPSs of humpback whales.

Whales from each of the listed DPSs travel to U.S. coastal waters specifically to access energy-rich feeding areas, and the high degree of loyalty to specific locations indicates the importance of these feeding areas. Although humpback whales are generalist predators and prey availability can vary seasonally and spatially, substantial data indicate that the humpback whales diet is consistently dominated by euphausiid species (of genus *Euphausia*, *Thysanoessa*, *Nyctiphanes*, and *Nematoscelis*) and small pelagic fishes, such as northern anchovy, Pacific herring, and Pacific sardine (Nemoto 1957, Nemoto 1959, Klumov 1963, Rice Krieger and Wing 1984, Baker 1985, Kieckhefer 1992, Clapham *et al.* 1997; See “Diet and Feeding Behavior” and Appendix A).

Within their feeding areas, humpback whales must have access to adequate prey resources to meet the nutritional and energy demands associated with individual survival, growth, reproduction, lactation, seasonal migrations, and other normal life functions. Fat storage has been linked to reproductive efficiency in other species of large, migratory, baleen whales (Lockyer 2007), and some evidence suggests that variation in prey availability during summer is directly connected to variation in annual reproductive rates for humpback whales in the following year (Clapham 1993). Calf condition has also been significantly correlated with female body condition (low calf body condition with lower female condition) for humpback whales in Australia (Christiansen *et al.* 2016), and as noted previously, lactating females are estimated to have the highest energy demands (McMillan 2014; see “Energy Requirements”). During migrations and while in breeding areas, humpback whales subsist completely or almost so on the stored fat within their blubber. Such periodic fasting occurs in other baleen whales and has been demonstrated in humpbacks by direct observation, empty stomachs of whales in breeding and migratory regions, and by the substantial increase in body weight that occurs during the feeding season (Dawbin 1966, Chittleborough 1965, Lockyer 1981). Although Baraff *et al.* (1991) noted occasional feeding by a small number of humpback whales in breeding grounds (likely when sufficient aggregations of prey were encountered), such occurrences are considered rare. In addition, the low productivity typical of humpback breeding habitats is generally not likely to provide prey in sufficient densities to make feeding energetically profitable (Baraff *et al.* 1991).

Given the energetic demands of lunging and other prey capture techniques, foraging is only expected to be profitable above some lower threshold for an energetic return, and evidence suggests that humpback whales will only feed when they encounter suitable concentrations of prey (see “Energy

Requirements”). Within their North Pacific feeding areas, humpback whales have often been observed in association with, or specifically targeting, dense aggregations of prey (e.g., Bryant *et al.* 1981, Krieger and Wing 1986, Goldbogen *et al.* 2008, Sigler *et al.* 2012, Witteveen *et al.* 2015). Thus, it is essential that the whales not only have reliable access to prey within their feeding areas, but that prey are of a sufficient density to support feeding and the build-up of energy reserves.

Other Features Considered

Sound

The CHRT had in-depth discussions regarding the importance of sound to humpback whales and whether the available data supported the identification of a sound-related essential feature of the whales’ occupied habitats. Ultimately, although the CHRT members fully acknowledged that the whales’ sensory ability to perceive and process sounds within their environment is an important aspect of their biology, the majority of the CHRT (with 2 members unsure and 1 dissent) agreed that we cannot currently identify a sound, sound levels, or a certain soundscape feature that is essential to the conservation of humpback whales. The multiple reasons for this conclusion are summarized here.

Humpback whales occur within a wide range of soundscapes, and conclusions regarding particular sound-related habitat requirements for humpback whales are difficult to draw. Anthropogenic sounds are present in all parts of humpback whale habitat. However, some areas have more sources and higher levels of anthropogenic sound than others. Sightings data clearly demonstrate that humpback whales in the North Pacific routinely use and occupy relatively less noisy areas (e.g., Prince William Sound) as well as some of the noisiest areas along the U.S. West Coast (e.g., southern California, Redfern *et al.* 2017). Ocean noise is increasingly being acknowledged as a management concern for marine mammals, and impacts range from direct physical injury to behavioral disturbances (Hildebrand 2009, Gomez *et al.* 2016). A sizeable body of research indicates that humpbacks and other baleen whales exhibit a range of responses to various noise disturbances (e.g., vessel traffic, underwater explosives, seismic surveys) - with some studies showing clear impacts on individual animals or evidence of altered behaviors (e.g., Ketten *et al.* 1993, McCauley *et al.* 2000, Sousa-Lima and Clark 2008, Blair *et al.* 2016), and other studies reporting no or limited responses to noise (e.g. Lien *et al.* 1993, Croll *et al.* 2001, Weinrich and Corbelli 2009, Dunlop *et al.* 2017a, Wensveen *et al.* 2017; reviewed in Richardson *et al.* 1995 and NRC 2003).

Based on the data available, the threat of anthropogenic noise received a “low” rating for all DPSs of humpback whales in the recent NMFS Status Review (out of possible ratings of unknown, low, medium, high, and very high; Bettridge *et al.* 2015). Several studies have indicated that humpback whales, which are predicted to have a low-frequency hearing range of roughly 7 Hz to 35 kHz (NMFS 2018), may even habituate to certain low-frequency noises (Sivle *et al.* 2016, Di Clemente *et al.* 2018, Teerlink *et al.* 2018) – one of the most ubiquitous sources of which is commercial vessels (Hildebrand 2009). For example, in a study conducted near Juneau, Alaska, where whale-watching activity is relatively intense, Di Clemente *et al.* (2018) monitored activity budgets of humpback whales during the summer feeding season and

detected no reduction in foraging time when whales were in the presence of vessels, relative to when vessels were absent. In this study, humpback whales were actually more likely to continue feeding in the presence of vessels than without vessels present (Di Clemente *et al.* 2018). In a follow-up to this study, Schuler (2019) found that whales did not change their behavioral state (e.g., feeding, resting, traveling) based on the presence of vessels. However, they did exhibit higher deviation in linear movement (change in direction at the surface), increased swimming speed, and shorter inter-breath intervals when boats were present. With each additional vessel, the linear deviation further increased and the inter-breath interval further shortened, indicating that the response was greater as the number of vessels present (and presumably associated vessel noise) increased. While Schuler (2019) and others have demonstrated short-term behavioral responses to vessel disturbance and other noise, it is difficult to evaluate if these stimuli have lasting impacts that could potentially cause a decrease in fitness. In an attempt to evaluate longer-term impacts from vessel disturbance in the same study area (Juneau, Alaska), cortisol concentrations (a steroid hormone associated with stress level) were measured from biopsy blubber samples (Teerlink *et al.* 2018). Samples were collected from humpback whales in the Juneau area at the end of the tour season and compared to samples collected from humpback whales in more remote areas with little vessel traffic in the same month. No increase in blubber cortisol concentrations was found in whales that had been present in the Juneau tour area for the summer, indicating that they did not show physiological signs of long-term stress response relative to whales from other areas (Teerlink *et al.* 2018). In fact, in spite of the substantial contrast in vessel disturbance levels, the cortisol concentrations in the Juneau area were lower than they were for two of three control areas (Teerlink *et al.* 2018). These results suggest that humpback whales in this area may have habituated to the high numbers of whale watching vessels and the associated vessel noise.

Humpback whales have also exhibited flexibility and adaptability to increases in ambient noise. Such behavioral plasticity may allow the whales to reduce acoustic interference with natural auditory signal processing (i.e., acoustic masking). For example, data from two separate studies, one conducted in Australia and one in Glacier Bay, Alaska, indicate that humpback whales will change the amplitude of their calls in response to increases in ambient noise (referred to as the Lombard effect) Dunlop *et al.* 2014, Fournet *et al.* 2018). Two other studies reported that humpback whale songs lengthened when exposed to low-frequency active (LFA) sonar (Miller *et al.* 2000, Fristrup *et al.* 2003). Humpback whales have also been found to change signaling strategies from vocal to non-vocal communications (e.g. breaches and tail slaps) in response to increased wind speeds and background noise (Dunlop *et al.* 2010). Dunlop (2016) compared the responses of humpback whales exposed to natural (wind) versus anthropogenic noise (vessels), and found that the whales increased their vocalizations levels and increasingly relied on non-vocal communications in response to wind noise. However, the whales showed neither response when exposed to vessel noise, suggesting that the whales may not necessarily be able to compensate to the same extent to different sources of noise (Dunlop 2016).

Behavioral responses of humpback whales to noise are highly variable across habitats and even among individual whales, and many factors can influence whether and how noise will affect a whale, including

past exposure to a noise, individual noise tolerance, age, breeding status (with or without calf), and current behavioral state of the whale (e.g., resting versus migrating; Malme *et al.* 1985, Krieger and Wing 1986, Richardson *et al.* 1995, Richardson and Würsig 1997, NRC 2003, Sivle *et al.* 2016, Wensveen *et al.* 2017). Responses to noise are also dependent on characteristics of the noise— e.g., pulse or non-pulse, moving or stationary noise, novel or common, etc. (Richardson *et al.* 1997, Southall *et al.* 2007, Ellison *et al.* 2012). As one example, in controlled playback experiments using killer whale sounds and separate sonar transmissions, humpback whales exhibited more severe responses to killer whale noises than sonar (though they did demonstrate avoidance responses to both) (Sivle *et al.* 2015). Adding to this overall complexity is the fact that understanding of humpback whale hearing remains quite limited (Houser *et al.* 2001, NMFS 2018).

Given the highly diverse and spatially broad areas occupied by humpback whales, as well as the mixed responses of humpback whales to noise, the CHRT could not define a sound feature that is essential to the conservation of humpback whales nor identify specific areas where such a feature could be found within the occupied ranges of the DPSs. Ambient sound or the “soundscape” is relevant to the whales’ ability to communicate and receive sounds within the marine environment no matter where the whales occur, and sound or a soundscape *per se* does not appear to be associated with habitat use or occupancy. Instead, humpback whales appear to be highly flexible in their ability to use and occupy habitats with varying soundscapes. This flexibility may be in contrast to other cetaceans that have very limited or restricted distributions and for which noise impacts such as habitat displacement are likely to have measureable effects on stress, foraging success, survival, reproduction, etc. (Forney *et al.* 2017). We note, however, that substantial data gaps and various shortcomings for much of the existing literature (such as limited duration of assessments, limited geographic scale of observations, uncertainty regarding actual mechanism for observed responses, uncertainty in the received levels of noise, and other confounding factors associated with the particular study locations) prevent a clear understanding of the acoustic ecology of humpback whales. Furthermore, broader and longer-term consequences of noise on the fitness and viability of humpback whales are not yet known (NRC 2003; Wartzok *et al.* 2003; NRC 2005, Bettridge *et al.* 2015, Gomez *et al.* 2016). Thus, although the CHRT ultimately concluded that sound could not be supported as an essential habitat feature at this time, improved understanding of the acoustic ecology of humpback whales may eventually lead to a different conclusion. The CHRT noted that metrics and tools by which managers can assess adverse impacts on the whales themselves are currently available (e.g., NMFS 2018), and that analyzing the impacts of noise on the whales is already required under the MMPA and the jeopardy standard of section 7 of the ESA. Lastly, the CHRT noted, that should data indicate that anthropogenic noise is interfering with humpback whales’ ability to detect, capture, or access prey within their feeding areas, such an effect would constitute an impact on the prey essential feature as defined above.

Migratory Corridors and Passage

Given the known migratory behaviors of humpback whales and the recent and growing concern regarding entanglement and ship strikes of humpback whales, especially along the U.S. West Coast, the

CHRT explored the possibility of defining a migratory corridor or passage-related essential feature. The CHRT considered the best available data and also consulted with biologists with expertise in satellite telemetry and entanglement of humpback whales. Ultimately, and for reasons summarized below, the CHRT concluded that a migratory corridor or passage feature could not be identified, either between or within the seasonal habitats occupied by humpback whales within U.S. waters.

In terms of a migratory “corridor,” the available satellite tagging data do not indicate that there is a defined route for humpback whales traveling between the seasonal breeding and feeding areas in the North Pacific (Mate *et al.* 2007, Lagerquist *et al.* 2008, Mate *et al.* 2018). Of the three DPSs of humpback whales considered in this report, the available satellite data are for the Mexico DPS, and we are not aware of any publicly available satellite tracked migrations for whales from either the Western North Pacific or Central America DPS. Satellite tagged whales from the Mexico DPS have been documented to use very nearshore waters, offshore waters within the U.S. Exclusive Economic Zone (EEZ), as well as waters out beyond the U.S. EEZ when transiting between winter breeding areas and summer feeding areas (see Figures 9 and 10; Lagerquist *et al.* 2008, Mate *et al.* 2018). For Mexico DPS whales, when complete migratory routes have been captured, the telemetry data also indicate that the whales don’t necessarily maintain a constant distance from shore, and at different points along their migration may be closer or farther from shore (D. Palacios, OSU, pers. comm., June 6, 2018, Mate *et al.* 2018). The depth or a depth range that the whales typically occupy while undergoing their seasonal migrations is also not yet resolved, although it has been hypothesized that the whales generally stay within the upper 50 m of the water column while migrating (D. Palacios, pers. comm. June 8, 2018). Satellite tagging of whales within the feeding range of all three DPSs has occurred, and while DPSs of origin was not necessarily confirmed in all studies, results consistently show considerable variation in the fine-scale movement patterns of the individual whales both within and across years, suggesting that the whales are making independent decisions regarding their movements (Kennedy *et al.* 2014, Mate *et al.* 2018). Thus, the CHRT concluded it is not currently possible to spatially identify any consistently used migratory corridors or define any essential migratory conditions for whales transiting between or within habitats of the three DPSs.

The conclusion by the CHRT regarding a migratory corridor is consistent with previous critical habitat designations for large migratory species such as Pacific leatherback sea turtles (77 FR 4170, January 26, 2012) and North Atlantic right whales (81 FR 4837, January 27, 2016). In these cases, NMFS concluded that while supporting and protecting the ability of these species to migrate between important habitats was important to the conservation of the species, there was no clear migratory route or passage feature that could be defined. We also note that, as part of a multi-agency mapping effort (CetSound, <https://cetsound.noaa.gov/cetsound>), Biologically Important Areas (BIAs) were identified for cetacean species or populations within the U.S. EEZ. Of the four categories of BIAs - reproductive areas, feeding areas, migratory corridors, and small and resident populations – no migratory corridor BIAs have been identified to date for any population of humpback whales in any ocean (Ferguson *et al.* 2015b, see “Specific Areas,” below). Although the CHRT unanimously agreed that a migratory feature was not

supported at this time, we also noted the ongoing management concerns of ship strikes and entanglement. Humpback whales are observed regularly in and around fishing gear and in areas of high vessel traffic, and entanglement and ship strikes continue to pose threats to all three DPSs of humpback whales addressed here. While these threats will continue to be treated as “take” issues and managed as threats to the animals, the CHRT noted that should these or similar activities (e.g., large-scale aquaculture), either independently or in combination, prevent or impede the whales’ ability to access prey, that this could constitute a negative impact on the prey feature defined above.

Special Management Considerations or Protections

We have determined that the identified essential prey feature may require special management considerations or protections as a result of several activities or threats. First, prey availability may be reduced through ecosystem shifts driven by climate change, direct harvest in commercial fisheries, or a combination of these two factors. Prey abundance, quality, and accessibility may also be negatively affected by various forms of pollution in the marine environment as well as underwater noise. These four broad categories of actions or threats, which we discuss in more detail below, have the potential to result in negative impacts to the essential feature and the ability of feeding areas to support the conservation of listed humpback whales in the North Pacific.

In addition to these four categories, the prey essential feature may potentially require special management considerations and protections as a result of food competition with other predator species. Other predators, including fish, sea birds, and other baleen whale species, have diets that overlap with humpbacks whales, and it is conceivable that this could lead to inter-specific competition, especially during phases of poor ocean conditions and low productivity. However, as this threat is either hypothesized or not yet well understood, whether and the extent to which it would negatively affect the abundance of prey or access to humpback whale prey has not been established.

Climate Change

Multiple studies have detected changes in humpback whale prey abundance, quality, and distribution in association with climate shifts, particularly with ocean warming. The nature and extent of impacts have varied across study areas and species; however, in many cases, ocean warming has led to negative impacts on humpback whale prey species. For instance, in the CCE, during the anomalous warming of the upper ocean and weak upwelling in 2013 - 2016, often referred to as the “blob” or the “warm blob”, sharp decreases in euphausiid biomass, as evidenced by declines in both abundance and body length, were observed (Harvey *et al.* 2017, Peterson *et al.* 2017; see also <https://oceanview.pfeg.noaa.gov/cciea-plotting/?opentab=0&ind=10>). Varying responses to warming conditions during El Niño years has also been observed among euphausiid species off California, with some species (e.g., *E. pacifica* and *T. spinifera*) experiencing severe declines during El Niño years (Brinton and Townsend 2003). In the Gulf Alaska, effects of warming have been mixed across euphausiid species,

with *T. inermis* abundance decreasing in warm years, and *E. pacifica* abundance slightly increasing in warm years (Pinchuk *et al.* 2008). This difference between species' responses may have been due to differences in the timing of spawning (April versus May-August), differences in prey (*E. pacifica* may utilize more food sources), and/or other mechanisms (Pinchuk *et al.* 2008). In the Bering Sea, based on samples collected annually during 2002-2009, euphausiid biomass was also shown to decline as temperatures warmed during 2003-2006, and subsequently increase as temperatures declined during 2006- 2009 (Coyle *et al.* 2011).

Fish species targeted by humpback whales may also be negatively impacted by warmer ocean conditions. For example, in comparisons of samples collected in the Northern California Current region during years of cool (2011, 2012), warm (2000, 2002), and intermediate (2015, 2016) conditions, body condition of northern anchovy, Pacific herring, and Pacific sardine were better in cool years compared to warm years, and significantly so for anchovy and herring (Brodeur *et al.* 2018). However, within the eastern Pacific, sardines have been shown to have improved reproductive success in warm years (Jacobson and McCall 1995, Bakun and Broad 2003), and Agostini *et al.* (2007) concluded that one of the key drivers of this pattern was decreased predation on larval sardines in warm years.

Climate change may also alter the spatial and temporal distributions of humpback prey species. For instance, during the "warm blob" event, sardine had earlier spawning and appeared farther north within the Northern California Current than in previous years (Auth *et al.* 2018). Shifts in prey abundance and distributions may lead to corresponding shifts in marine mammal distributions (King *et al.* 2011). Such a response was reported for blue, fin, and humpback whales in Monterey Bay, California, the densities of which all declined with El Niño -associated declines in euphausiids (Benson *et al.* 2002).

Related or indirect impacts of climate change, such as eutrophication, harmful algal blooms, and ocean acidification, may have additional impacts on the humpback prey essential feature. For instance, eutrophication may facilitate blooms of gelatinous zooplankton (jellyfish, Purcell *et al.* 1999, 2007), and evidence suggests that jellyfish can out-compete small pelagic forage fish for prey under eutrophic conditions (Haraldsson *et al.* 2012). As another example, the "warm blob" event contributed to an increase in toxic diatoms (*Pseudo-nitzschia*), resulting in a large, prolonged harmful algal bloom in 2015 that extended from California to the Gulf of Alaska (Peterson *et al.* 2017). A risk assessment by McKibben *et al.* (2017) provided evidence that warmer ocean conditions are associated with elevated levels and prevalence of the neurotoxin domoic acid (produced by diatoms in genus *Pseudo-nitzschia*) in shellfish. The authors also hypothesized that if warming events become more frequent, there may also be an increase in the frequency and duration of domoic acid events. Ocean acidification, which is driven by increasing atmospheric concentrations of carbon dioxide, could also have potential negative impacts on fish species if acidification results in declines in their calcareous plankton prey species (Bakun *et al.* 2015). However, model simulation of impacts of pH changes on the CCE indicated only very small, negative impacts of acidification on pelagic fish (such as sardine and anchovy) and mammals (Marshall *et al.* 2017).

Consequences of climate-driven and climate-related reductions in the quality and abundance of prey species can cascade upwardly through ecosystems by decreasing energy transfers to higher trophic levels and potentially even causing reproductive failures and die-offs of some predators (Coyle *et al.* 2011, Zador and Yasumiishi 2017 and 2018, Bordeur *et al.* 2018, Jones *et al.* 2018). Observations of whales with poor body condition, called “skinny whales” due to their emaciated appearance, have been reported in recent years in Prince William Sound and Glacier Bay, Alaska (Straley *et al.* 2018; pers. comm. C. Gabriele, May 22, 2018, and see <https://irma.nps.gov/DataStore/DownloadFile/620535>). The lowest calving rates on record (since 1985) have also been observed in recent years (2016–2018, <https://irma.nps.gov/DataStore/DownloadFile/620535>) in Southeast Alaska, and juvenile return rates to the area are also low (Gabriele and Neilson 2018). It is not yet clear whether nutritional stress or some other factor (e.g., parasites, disease) is the cause of the poor body condition and observed low calving rates of these whales, but some researchers hypothesize that reduced prey availability and/or quality driven by the marine heat wave of 2013–2016 and other climate factors is the likely cause (Gabriele and Neilson 2018).

Commercial Fisheries

Within the areas under consideration for designation, a few commercial fisheries directly target prey species that form a major part of the humpback whale diet (e.g., Pacific herring, northern anchovy), and other commercial fisheries can incidentally capture important prey species. This creates the potential for direct competition between humpback whales and certain fisheries (Trites *et al.* 1997). Humpback whales target large, dense schools of prey, and it is very likely that there is a density threshold below which humpback whales will not feed or cannot feed effectively due to trade-offs with the energetic demands of feeding. Consequences of prey depletion as a result of fishing activities are also likely to be exacerbated in years when alternative humpback whale prey species are naturally low in abundance due to climate or environmental factors.

Sufficient depletion of prey on the feeding grounds can lead to nutritional stress, which in turn can lead to decreases in body condition, size, reproductive output, and survival (as in Steller sea lions, Trites and Donnelly 2003; gray whales, Bradford *et al.* 2012; right whales, Seyboth *et al.* 2016). Humpback whales only rarely feed during migration and while on breeding grounds, so access to sufficient quantities of prey and the resulting buildup of fat stores while on the feeding grounds is critically important to supporting humpback whale life history needs, including reproduction (as in fin whales, Lockyer 2007). For humpback whales in the Atlantic Ocean, there is some evidence that variation in prey availability during the summer may be connected to variation in annual reproductive rates in the following year (Clapham 1993).

One example of a fishery that operates within the feeding range of humpback whales and targets humpback prey is the state-managed herring fishery in Alaska. Pacific herring (*Clupea pallasii*) or their eggs are harvested in locations extending from Southeast Alaska to Dutch Harbor and north to Norton Sound (http://www.adfg.alaska.gov/static/fishing/PDFs/commercial/active_herring_map.pdf).

Commercial fishing of other humpback prey species, including capelin, euphausiids, sand lance, and eulachon, is currently prohibited within federal waters of the Bering Strait/Aleutian Islands area and in the Gulf of Alaska (see 50 CFR Part 679, Amendment 39 to the Gulf of Alaska Groundfish Fishery Management Plan (FMP)). This management measure was adopted because it was recognized that these forage fish serve as a critical food source for many other species of marine mammals, seabirds, and fish (63 FR 13009, March 17, 1998). While limited incidental catch of these fish species does occur, this bycatch is managed by take limits and restrictions on processing and sale (Ormseth *et al.* 2016, Ormseth 2017).

As another example, Pacific sardine (*Sardinops sagax*) and northern anchovy (*Engraulis mordax*) are targeted off the U.S. West Coast in commercial fisheries managed by the Pacific Fisheries Management Council (PFMC) under the Coastal Pelagic Species Fishery Management Plan (CPS FMP). Under this FMP, the Pacific sardine fishery has been closed since the 2015 fishing season (allowable catch set to zero) due to predicted low biomass estimates; however, there are allowances for incidental catch of CPS species in CPS and non-CPS fisheries, and directed harvest is allowed for live bait, recreational, and tribal fisheries (Hill *et al.* 2017, see <https://www.pcouncil.org/coastal-pelagic-species/current-season-management/>). Fluctuations in biomass are common for Pacific sardine (Chavez *et al.* 2003), and the fishery will likely re-open with sufficient population increases. The anchovy fishery remains active; however, this species is landed in relatively low numbers and is managed by monitoring trends in landings and making qualitative comparisons to available abundance data (no formal stock assessment) (PFMC 2018). In March 2006, the CPS FMP was amended to prohibit harvest of all species of krill in the U.S. EEZ. While not specific to humpback whales, that amendment was passed to prevent the development of a commercial fishery that could deplete krill stocks and thereby impact many other predators in the ecosystem. Similarly, based on Amendment 25, commercial fisheries are prohibited from developing for other currently unfished and non-managed forage fish off the U.S. West Coast (including sand lance, which have been noted as humpback prey, and smelt).

Pacific herring biomass remains at low levels in Prince William Sound and current biomass for herring across Southeast Alaska has decreased since peak biomass levels in 2008 - 2011 (Pegau *et al.* (2018) and Hebert and Dressel (2018) in Zador and Yasumiishi 2018). Relative to a peak in 2011, Pacific herring stocks are continuing to decline in Southeast Alaska (with the exception of Sitka Sound) from unknown causes (Hebert and Dressel (2018) in Zador and Yasumiishi 2018). Some evidence suggests that the natural fluctuations in the population sizes of the small pelagic fish species consumed by humpbacks (Chaves *et al.* 2003, McClatchie *et al.* 2017) may be exacerbated by fishing activities, resulting in more extreme and more frequent collapses of stocks (Essington *et al.* 2015).

Pollution

Although pollution was not identified as a significant threat to any of the North Pacific DPSs of humpback whales in the recent status review (Bettridge *et al.* 2015), humpback whales can accumulate contaminants in their blubber through ingestion of contaminated prey. Consumption of contaminated

or low quality prey may negatively affect the health, population growth, and ultimately the recovery of listed humpback whales. Although they do not consume prey species from higher trophic levels, humpback whales are still susceptible to bioaccumulation of lipophilic contaminants because they have long lifespans and large fat deposits in their tissues. Some contaminants may also be passed to young whales during gestation and lactation (as in fin whales, Aguilar and Borrell 1994). In comparisons of samples collected from Northern Hemisphere feeding grounds, Elfes *et al.* (2010) reported that concentrations of contaminants within humpback whale blubber were high in southern California and in the Northern Gulf of Maine.

Organic pollutants, including petroleum products, organochlorine pesticides (OCPs), and polychlorinated biphenyls (PCBs), have the potential to directly impact the prey essential feature as defined above. Exposure to petroleum could kill the prey organisms, reduce their fitness through sub-lethal effects, and potentially disrupt the structure and function of marine communities and ecosystems. The biological effects of oil pollution include both acute effects (e.g., direct mortality of both adult and juvenile and larval life stages due to acute exposure) as well as sub-lethal effects to both adult and juvenile life stages due to acute and chronic exposure and indirect impacts to other organisms composing the pelagic ecosystem such as phytoplankton community structure, thereby impacting the forage base of fish species that serve as prey for humpback whales.

Other pollution-related concerns that may affect prey availability and quality include oil spills and algal blooms. Pollution from untreated industrial and domestic wastewater may be contributing to the occurrences of algal blooms. During algal blooms, toxins can become increasingly concentrated as they move up the food chain. Although much of the humpback whales' prey are lower trophic level species, four unusual mortality events have been documented in the Atlantic Ocean. During one event where 16 humpback whale carcasses were found, a portion of the humpback whales had saxitoxin poisoning and/or contained domoic acid; other whales were not sampled (Gulland 2006). In another event, 14 whales died after eating Atlantic mackerel that contained saxitoxin (Geraci *et al.* 1989).

Ocean Noise

Lastly, effects of noise on fish and zooplankton species, which is a topic of increasing research attention, may range from health and fitness consequences to mortality and reductions in abundance (Popper and Hastings 2009, Kight and Swaddle 2011, Radford *et al.* 2014). For example, there is evidence that marine seismic surveys can result in behavioral effects as well as significant injury and mortality of fishes and zooplankton (McCauley *et al.* 2017, Carroll *et al.* 2017); but, such impacts may be relatively short in duration and spatially limited (to within the survey footprint and extending out ~15 km) and may be minimized by ocean circulation (Richardson *et al.* 2017). Available research also suggests that other noise in the marine environment, such as impact pile driving, underwater explosives, and cargo ships, may have negative consequences on certain fish and invertebrate species by causing trauma or tissue damage, mortality (of various life stages), stress, avoidance, disruptions of schooling, or reduced foraging success (reviewed in Popper and Hastings 2009 and Weilgart 2017). Whether and how specific

humpback whale prey are currently being impacted by various noise sources and levels is not yet clear, but the available information is sufficient to indicate that underwater noise is posing a management concern for many fish and invertebrate species (Hawkins and Popper 2017). Finally, as mentioned earlier in this report, noise may negatively affect the prey such that the whales' ability to access and capture prey or carry out normal feeding behaviors is impacted, thus posing additional management concerns.

Unoccupied Areas

Section 3(5)(A)(ii) of the ESA authorizes the designation of specific areas outside the geographical area occupied by the species if those areas are determined to be essential for the conservation of the species. Regulations at 50 CFR 424.12(b)(2) require that we first evaluate areas occupied by the species and only consider unoccupied areas to be essential where a critical habitat designation limited to geographical areas occupied would be inadequate to ensure the conservation of the species.

Within the North Pacific Ocean, humpback whales historically ranged throughout all coastal areas of Asia and North America. Although humpback whale populations were greatly reduced throughout their range by commercial whaling (Rice 1978, Rice and Wolman 1982, Johnson and Wolman 1984), they still occur in areas where they were once targeted by commercial whaling operations, or they have returned to areas where they had not been observed for many years. For instance, humpback whales are common in the former whaling grounds off Port Hobron and Akutan, Alaska, where they were once heavily exploited (Zerbini *et al.* 2006). Along the U.S. West Coast, humpback whales have recently returned to the Salish Sea (Strait of Juan De Fuca, Puget Sound, Strait of Georgia) where a large increase in sightings was reported for 2014 (Calambokidis *et al.* 2017). Humpback whales were targeted in the Salish Sea in the early 1900s and thought to have been eliminated from this area (including the Strait of Georgia) (Gregs 2000, Trites 2014). Additionally, in 2016, humpback whales were commonly observed within San Francisco Bay inside of the Golden Gate Bridge, which had been a rarer occurrence in previous years; and, in 2015 and 2016, humpback whales were regularly sighted within the Columbia River, where the whales were not known to occur in previous years (Calambokidis *et al.* 2017). The NMFS 2017 Marine Mammal Stock Assessments for the Western and Central North Pacific regions conclude that humpback whales are currently found throughout their historical feeding range (Muto *et al.* 2018). Because ESA-listed humpback whales are considered to occupy their entire historical range that falls within U.S. jurisdiction, we conclude that a designation limited to geographical areas occupied by humpback whales would be adequate to conserve the three listed DPSs.

Specific Areas

As discussed earlier in this report, occupied critical habitat is defined in section 3(5)(A) of the ESA as "specific areas" that contain the essential feature(s). Thus, after the CHRT had identified the occupied

geographical range and determined the essential prey feature, the next step towards identifying areas that could be considered for designation as critical habitat was delineating the specific areas containing the essential feature. Delineation of specific areas is done “at a scale determined by the Secretary [of Commerce] to be appropriate” (50 CFR 424.12(b)(1) and (2)). Regulations at 50 CFR 424.12(c) also require that each critical habitat area be shown on a map. In making decisions about the scale and boundaries for the specific areas, the CHRT considered, among other things, the scales at which biological data are available and the availability of standardized geographical data necessary to map boundaries. Because NMFS’s implementing regulations allow for discretion in determining the appropriate scale at which specific areas are drawn, the CHRT was not required to, nor was it possible to, determine that each square inch, acre, or even square mile independently met the definition of “critical habitat.” The main goal of the CHRT was to provide a clear description and documentation of boundaries for areas containing the identified essential feature. This is ultimately crucial to ensuring that federal action agencies are able to determine whether their particular actions may affect the critical habitat. Another goal was to delineate specific areas in a manner that would facilitate subsequent analyses for each humpback whale DPS under section 4(b)(2) of the ESA (e.g., consideration of economic impacts).

Following a review of the best available data, the CHRT delineated 19 specific areas along the coasts of Alaska, Washington, Oregon, and California that meet the definition of critical habitat for one or more of the three DPSs of whales (Figure 15). This section of the report discusses the process applied by the CHRT in selecting boundaries for each specific area and summarizes the relevant data indicating how each area meets the definition of critical habitat for a given humpback whale DPS.

Several decision rules were applied to the process by which the CHRT delineated the 19 units of critical habitat. First, the CHRT applied a decision-rule that humpback whale BIAs would remain intact within a particular specific area unless there was a compelling reason to change or divide it, as in the case of Unit 2, which is explained below (see Figures 16 -18). As noted earlier, the humpback whale BIAs have all been identified as “feeding” BIAs, which are defined as follows:

Areas and times within which aggregations of a particular species preferentially feed. These either may be persistent in space and time or associated with ephemeral features that are less predictable but are located within a larger area that can be delineated” (Ferguson *et al.* 2015b).

As discussed in Van Parijs (2015) and Ferguson *et al.* (2015b), BIAs were developed for cetaceans species within all regions of the United States through rigorous reviews of survey data and habitat models by multiple teams of scientists. BIAs represent areas and times where cetacean species occur and engage in important behaviors, and they can be one of four types: reproductive areas, feeding areas, migratory corridors, and areas where small and resident populations are concentrated. BIAs were identified to inform regulatory, management, and conservation decision-making by NOAA, other federal agencies,

and the public. While the BIAs are non-regulatory designations and were not intended to be synonymous with critical habitat under the ESA, they were regarded by the CHRT as very informative to our review of areas that meet the definition of critical habitat for humpback whales.

Second, for U.S. West Coast areas, the CHRT applied the results of a habitat model for the CCE that incorporated 275 humpback whale sightings from seven systematic line-transect cetacean surveys conducted in summer and fall (July-December) between 1991 - 2009 (Becker *et al.* 2016) and a habitat model for southern California (i.e., Units 16 – 19) that incorporated 53 humpback whale sighting from 20 surveys conducted between 2005 and 2015 during winter and spring (January- April, Becker *et al.* 2017). Predictions from the summer/fall models were made for the entire U.S. West Coast from the coast to 300 nmi offshore (the study area was approximately 1,141,800 km²). Predictions from the winter/ spring models were made in a subset of this region: south of 38°N and east of 125°W (the study areas was approximately 385,460 km²). The Becker *et al.* 2016 and 2017 models (Figure 17) summarize expected humpback whale distributions in the CCE over a long time-period and incorporate oceanographic variability observed during the surveys. While other models are available, they do not provide the same summary of long-term, expected distribution patterns. For example, Becker *et al.* (2018) used the same data plus data collected in 2014 to explore how well three models, differentiated by the habitat variables considered, predicted a novel year. It is not appropriate to use these models to delineate critical habitat because the focus of these analyses was comparing candidate models for making forecasts, rather than providing a long-term summary of expected distributions.

The Becker *et al.* (2016 and 2017) models predicted humpback whale abundance in approximately 10 x 10 km grid cells. The Becker *et al.* (2016) summer/fall models predicted an average of approximately 1,159 humpback whales in the CCE study area between 1990 – 2009. The Becker *et al.* (2017) winter/spring models predicted approximately 1,490 humpback whales in the smaller central and southern California study area between 2005-2015. There is uncertainty associated with these numbers, particularly from inter-annual variability. Humpback whale abundance estimated using mark-recapture techniques off California and Oregon increased approximately 7% per year between 1990-2008; estimates based on 4-year samples and Chao's model accounting for individual heterogeneity, ranged from 797 whales (1991-1994) to 2,409 whales (2007-2010, Calambokidis *et al.* 2017). Consequently, the Becker *et al.* (2016) and Becker *et al.* (2017) model abundances do not represent the absolute number of whales and are only provided here to give a sense of the relative number of whales in the study area.

Cells containing the highest 90% of the predicted study area abundance were used to help delineate the offshore extent of the specific areas (Figures 18). (All or 100% of the predicted abundance had a distribution that extended out to and even beyond the U.S. EEZ.) The Becker *et al.* (2016 and 2017) predictions shown in Figure 17 also contributed to delineating the north/south boundaries between the specific areas. As no such coast-wide habitat model is available for Alaska, the CHRT relied on published surveys and available sightings data. Where available, humpback whale sightings data were mapped and overlaid with the BIAs to help select boundaries between specific areas.

Lastly, for applicable habitat units, the CHRT also considered the feeding area ranges generated from 90% fixed kernel density distributions derived from satellite telemetry data for humpback whales exhibiting area restricted searches (ARS), which are indicative of feeding behavior (unpublished data, OSU; Mate *et al.* 2018). Because these ARS ranges were drawn based on feeding behavior data, the resulting polygons provided additional information and support for delineating particular areas as feeding areas (e.g., see Figures 5 and 6). When considering these data, the CHRT only used polygons representing the overlay of two or more individual whales (i.e., we did not consider movements representing just a single whale).

Along the coast of Alaska, selection of the shoreward boundary for habitat units (i.e., Units 1-10) was based on review of depth frequency histograms of humpback whale sightings (see Appendix B) recorded during SPLASH surveys in Alaska (see Calambokidis *et al.* 2008, supplemented with Glacier Bay National Park (GBNP) data for Glacier Bay and Icy Strait, courtesy of C. Gabriele) and during line transect surveys conducted in coastal waters off the Aleutian Islands and Alaska Peninsula during the summers of 2001-2003 (see Zerbini *et al.* 2006). Collectively, these sightings data represent results of different types of sampling effort (e.g., targeted small boat surveys, systematic line-transect surveys), different time-periods (2001-2003, 2004, 2005), and different study locations throughout the region. Rather than select any one particular data set or study over another, depth frequency histograms from all data sources were used to delineate the shoreward boundary.

Based on these data, the 1-m depth contour relative to mean lower low water (MLLW)) was selected for the habitat units in Alaska, with the exception of Unit 10. Humpback whales in Alaska have frequently been observed feeding very close to shore during high tide (J. Moran, AFSC, pers. comm., May 23, 2018), which comports with the CHRT's selection of the 1-m isobath. In Unit 10, however, the bathymetry becomes fairly complex, and mapping a 1-m MLLW depth contour line based on the available bathymetry data (Amante and Eakins 2009) caused sections of the southeastern Alaska BIA to be clipped out. For example, most of Glacier Bay, which supports high densities of humpback whales during summer months (June - August), was clipped out. For these reasons, the nearshore boundary in this one Alaska unit was drawn to correspond to the BIA boundary.

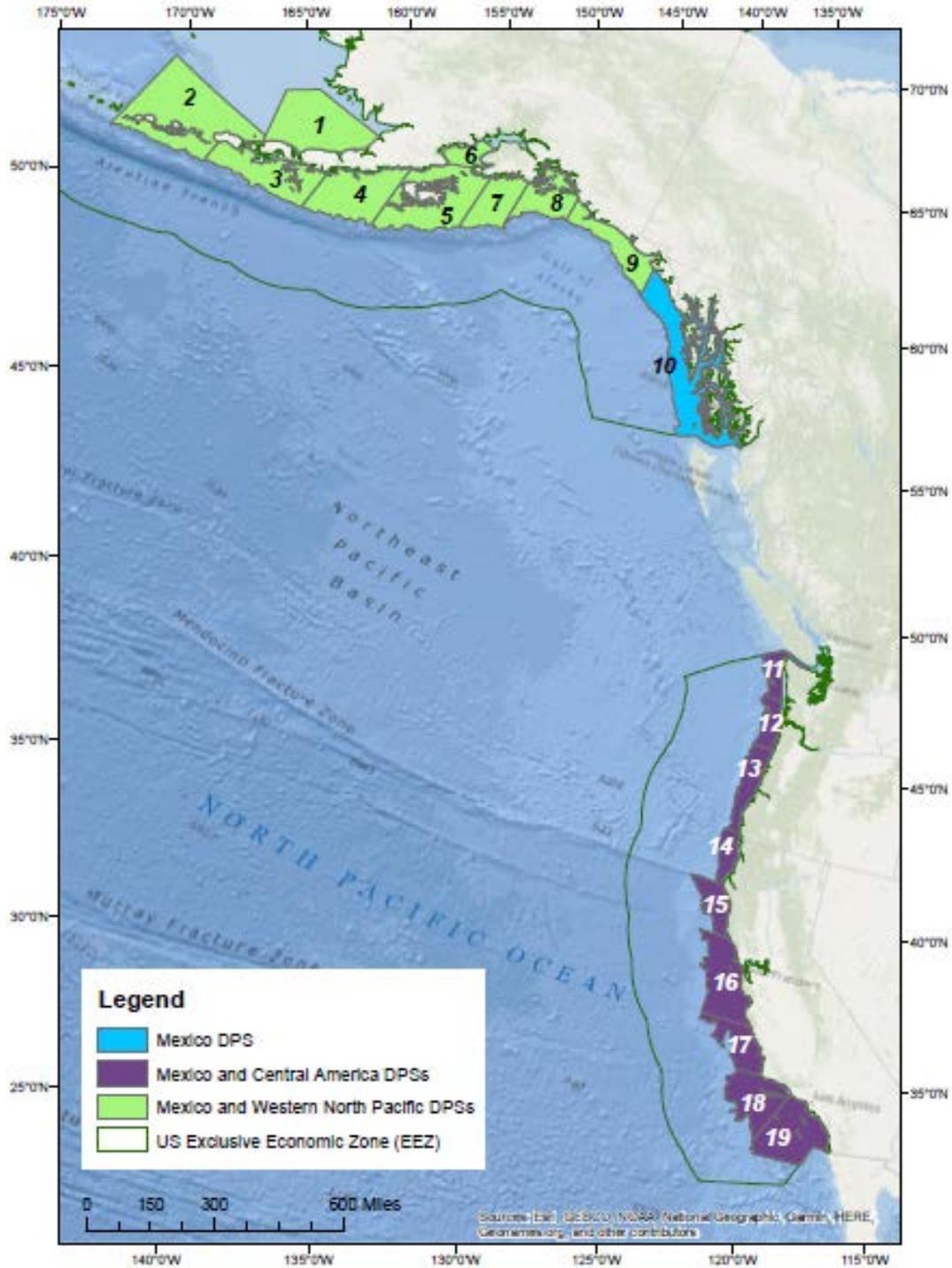


Figure 15. The 19 critical habitat units, encompassing a total of 207,908 nmi² of marine habitat. DPSs of whales documented or considered to occur in each unit is indicated by color.

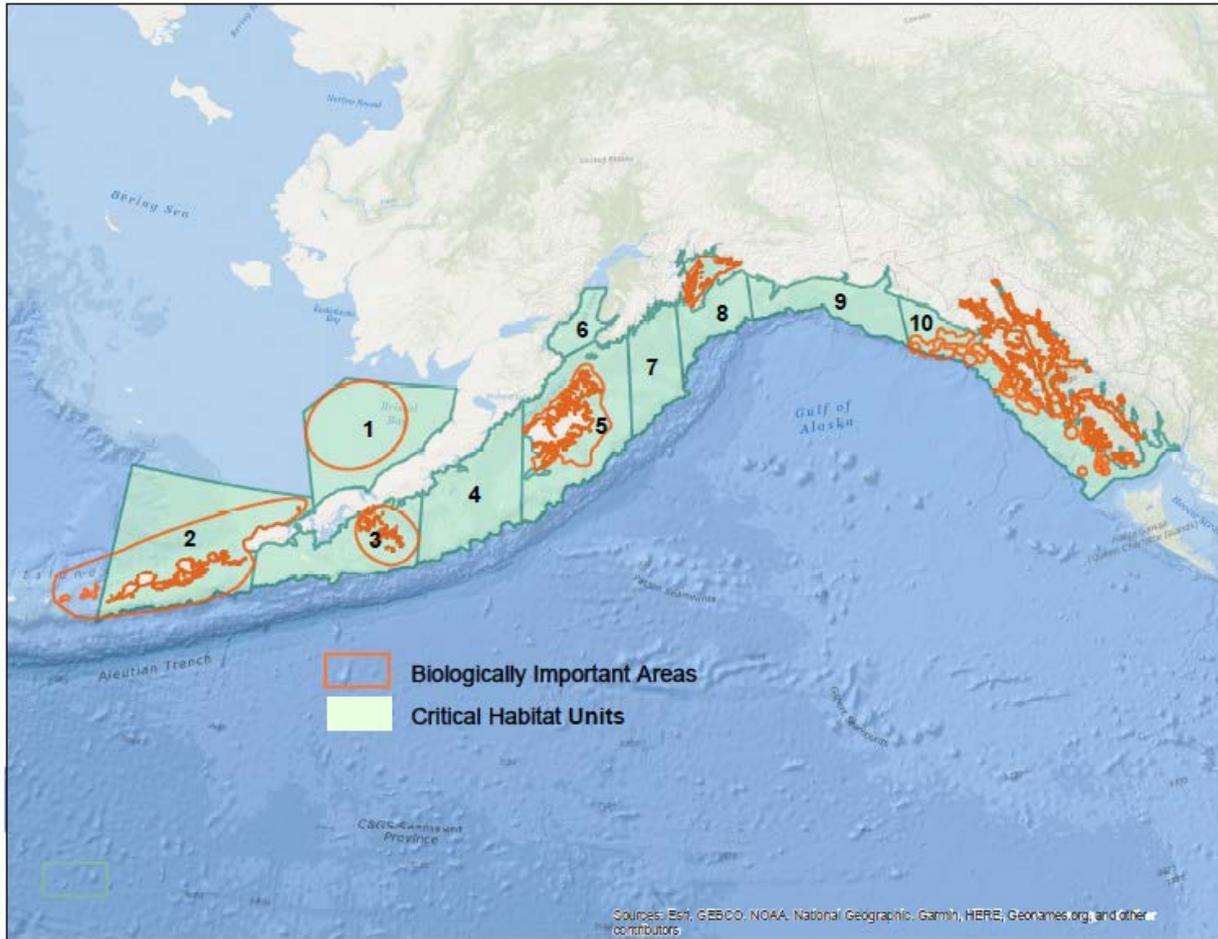


Figure 16. Location of humpback whale feeding BIAs in waters off Alaska and critical habitat Units 1-10. (Note: Some BIAs have shoreward boundaries. All BIA boundaries shown in orange.)

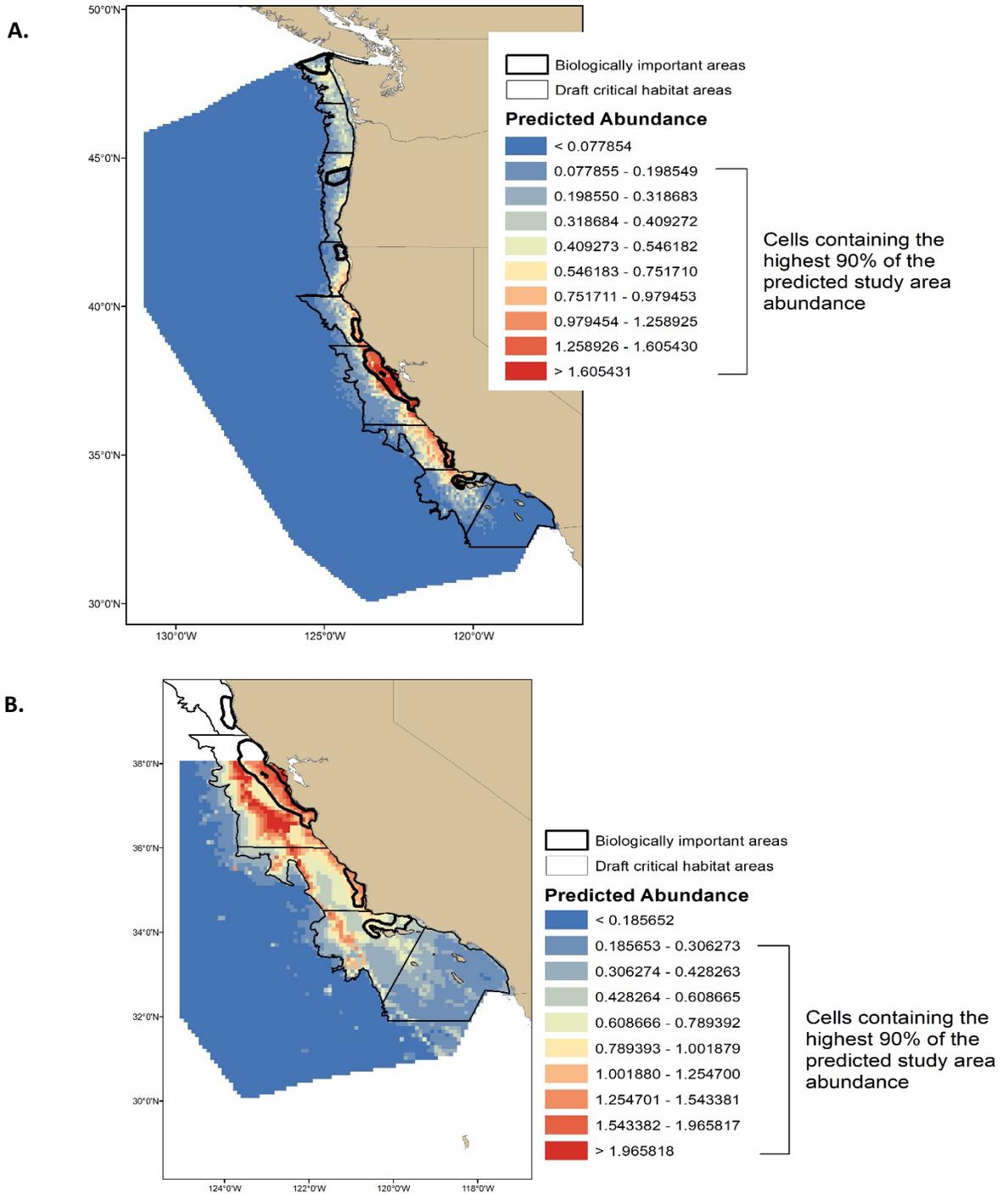


Figure 17. Abundance predicted in approximately 10 x 10 km grid cells by the A) Becker *et al.* (2016) summer habitat models and B) Becker *et al.* (2017) winter habitat models. The categories displayed in the maps divide the study area abundance into 10% intervals. Cells containing the highest 90% of the study area abundance were used to help delineate specific area boundaries and determine their offshore extent. Humpback whale feeding BIAs and critical habitat unit boundaries also shown.

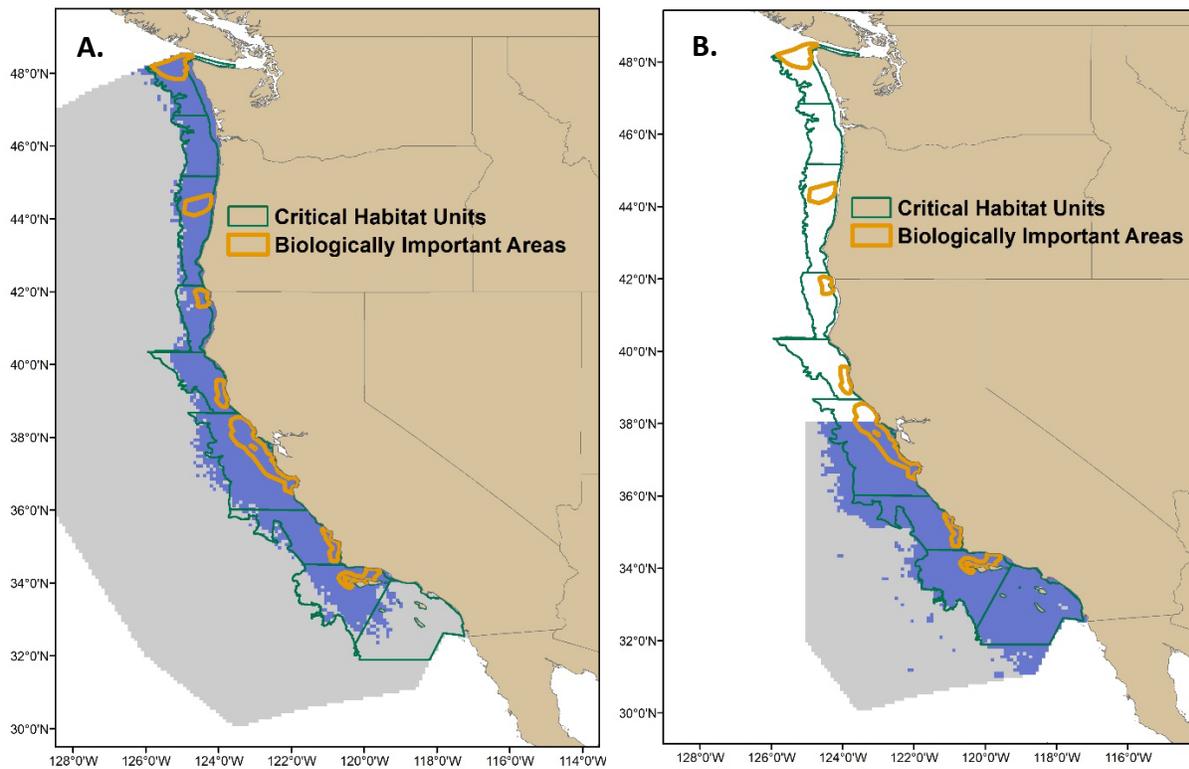


Figure 18. Critical habitat Units 11 -19, humpback whale feeding BIAs, and highest 90% of the predicted abundances based on A) Becker *et al.* (2016) summer habitat models and B) Becker *et al.* (2017) winter habitat models. The highest 90% of the study area abundance (shaded in blue) was used to help determine the offshore extent of specific area boundaries. Remaining 10% of predictions are shown as gray shaded areas.

Along the coasts of Washington, Oregon, and California, a shoreward boundary was selected in a similar fashion. Specifically, the CHRT reviewed separate depth frequency histograms of humpback whale sightings (Appendix B) generated from three data sources: 1) SPLASH surveys along the U.S. West Coast (see Calambokidis *et al.* 2008), 2) small boat survey data collected by Cascadia Research Collective (CRC) along portions of the U.S. West Coast in summers (CRC, data courtesy of J. Calambokidis), and 3) systematic line transect surveys collected over 7 years during 1991 - 2009 by the NMFS SWFSC (see Becker *et al.* 2016). All of these data sets contain limitations for identifying a shoreward critical habitat boundary. For example, the line-transect survey data were collected systematically, but contain a relatively small amount of effort in nearshore areas. The small boat surveys contain a substantial amount of effort in nearshore areas, but were conducted in areas known to contain humpback whales and that could be successfully surveyed by small boats. To overcome these limitations, depth frequency histograms from all data sources were used to delineate the shoreward boundary.

Based on these data, the 50-m isobath (from Amante and Eakins 2009) was selected as the shoreward boundary for most of the West Coast units. The exceptions were Units 16 and 17. Within both of these units, the 50-m isobath clipped out shoreward portions of humpback whale feeding BIAs, which were identified based on extensive humpback sightings data in those specific areas. Secondly, within Unit 16, 90% fixed kernel density distributions derived from satellite telemetry data for 13 humpback whales indicate that humpback whales exhibit area restricted search (ARS) behavior well shoreward of the 50-m isobath (unpublished data, OSU; Mate *et al.* 2018). Based on these additional data, a shoreward boundary of 15 m was selected for Unit 16, and a shoreward boundary of 30 m was selected for Unit 17. These depth contours more closely track with the nearshore boundary of the BIAs as well as the predicted humpback whale distributions based the habitat model of Becker *et al.* (2016).

More detailed rationales for the specific area delineations are provided for each of the 19 units below. We note that these delineations of specific units of habitat do not necessarily represent discrete feeding aggregations or populations of humpback whales - individual whales generally move across many of these boundaries. Brief information is also presented for each habitat unit regarding which DPSs of humpback whales have been definitively confirmed (photo-identified) as occurring within the area. Possible or assumed presence of DPSs in each area is not discussed here but is discussed in the next section (see “Conservation Value of Specific Areas”; see also Table C8, Appendix C).

Unit 1 - Bristol Bay

This unit is bounded along the northern edge by a line extending due west from Egegik (at 58° 14' N, 157° 28' W) to encompass the BIA. The boundary then extends southwest and then southward tangentially along the BIA to the coastline at Moffet Point (55° 27' N, 162° 35' W). As explained above, the nearshore boundary of this unit is the 1-m depth contour (relative to MLLW). This unit includes waters off Bristol Bay and Lake and Peninsula Boroughs, and a small portion of Aleutians East Borough. Unit 1 covers 19,279 nmi² of marine habitat.

Unit 1 boundaries were drawn based largely on the location of a humpback whale BIA, which was in turn identified based on results of systematic surveys reported in Clapham *et al.* 2012, Friday *et al.* 2012, and Friday *et al.* 2013, indicating high densities of humpback whales in this area (see Ferguson *et al.* 2015c). However, Unit 1 extends farther into Bristol Bay relative to the BIA to reflect sightings from 1999 aerial surveys of Bristol Bay (Friday *et al.* 2012) and sightings from the 2017 IWC-POWER survey (Matsuoka *et al.* 2018) indicating that humpback whales may also be common in these waters. The southern, nearshore boundary was drawn to accommodate the nearshore areas (within the 50 m isobath) indicated by sightings reported in Friday *et al.* 2013. Unit 1 does not extend into the intertidal portions of northern Bristol Bay based on the lack of detections of humpbacks in the small bays along the coast in northern Bristol Bay (Friday *et al.* 2012, Matsuoka *et al.* 2018, and J. Moran, AFSC, pers. comm. May 23, 2018). Humpback whale sightings collected within North Pacific right whale critical habitat during systematic vessel and aerial surveys conducted by NMML were considered but were not determinative of the area's boundaries given the high intensity of effort represented by those surveys. Surveys conducted during 2004 and 2006 -2010 within the eastern Bering Sea and that overlapped with a portion of Unit 1, indicated widespread and persistent concentrations of euphausiids in the survey area (Sigler *et al.* 2012).

Photo-identification data are not available to validate occurrences of particular DPSs within this unit; however, the available data suggest this area is a destination for whales from the Hawaii (HI), Western North Pacific (WNP), and Mexico (MX) DPSs (Baker *et al.* 2013). Five marked whales are also documented to have moved between this general region and the WNP breeding grounds (Omura and Ohsumi 1964).

Unit 2 – Aleutian Island Area

This unit includes waters along the northern side of Unimak Island, waters around Umnak and Unalaska Islands, and waters within Umnak and Unimak Pass. At its eastern edge, the northern boundary of this area extends from 55° 41'N/ 162° 41' W, tangentially along the northern edge of a BIA west out to 169° 30' W. The western boundary extends southward through Samalga Pass to a line drawn along the 2,000-m isobath on the south side of the islands, corresponds to the BIA boundary. This depth contour forms the southern boundary, which extends eastward to 164° 25' W. The nearshore boundary of this unit is the 1-m depth contour (relative to MLLW). This unit includes waters off the Aleutian East and Aleutian West Boroughs. Unit 2 covers 28,829 nmi² of marine habitat.

This area encompasses an identified BIA, which was drawn to include high density sightings of humpback whales as reported in Zerbin *et al.* 2006, Clapham *et al.* 2012, Friday *et al.* 2012, and Friday *et al.* 2013 (See Ferguson *et al.* 2015c). Telemetry and sightings data indicate that humpback whales use the coastal waters to the north and south of the islands as well as within the passes (Zerbin *et al.* 2006, Sigler *et al.* 2012, Kennedy *et al.* 2014). The western edge of the Unit 2, however, clips off the small portion of the BIA that extends west of Samalga Pass. This pass coincides with an abrupt oceanographic break, and the frequency of humpback whale sightings have been very low or absent west of Samalga

Pass (Zerbini *et al.* 2006; P. Wade, pers. comm., May 23, 2018). The northwestern edge of the Unit 2 also extends slightly north of the BIA, because available sightings data indicate humpback whales use waters north of Unimak Pass and along the middle and outer Bering Sea shelf and slope (Calambokidis *et al.* 2008, Friday *et al.* 2012, Friday *et al.* 2013, Matsuoka *et al.* 2018). Surveys conducted during 2004 and 2006 -2010 within the eastern Bering Sea, indicated widespread and persistent concentrations of euphausiids in this area (Sigler *et al.* 2012), and general additive models using environmental datasets from summers 2008- 2010 for the Eastern Bering Sea also predict relatively high levels of euphausiid biomass occurring within this area (Zerbini *et al.* 2016).

Photo-identification data indicate this area is a destination for whales from the HI, WNP and MX DPSs (Calambokidis *et al.* 2008).

Unit 3 – Shumagin Islands Area

This area extends from 164° 25' W eastward to 158° 39' W and encompasses the feeding BIA around the Shumagin Islands. The area is bounded on its southern edge (offshore) by the 1,000-m isobath. The nearshore boundary of this unit is the 1-m depth contour (relative to MLLW). This unit is mainly within the Aleutians East Borough, but includes a small portion of the Lake and Peninsula Borough. Unit 3 covers 13,162 nmi² of marine habitat.

This area was drawn from the boundary of Unit 2 eastward to encompass an identified BIA (Ferguson *et al.* 2015a). This BIA is within the 1,000-m isobath, which was selected as the offshore boundary for this unit. Surveys conducted within this area indicate that feeding aggregations of humpback whales consistently occur in coastal areas south of these islands and around the Shumagin Islands (Waite *et al.* 1999, Witteveen *et al.* 2004, Zerbini *et al.* 2006, Wynne and Witteveen 2013). During the University of Alaska's GAP Study surveys within this area, conducted across 14 feeding seasons, 654 individual humpback whales were identified out of 1,437 total sightings. Analysis of these sightings indicate a fairly high degree of site fidelity to this area, with an average annual rate of return of 37% (SD = 11.8%; Witteveen and Wynne 2016a). Surveys conducted in 1985 indicated that humpback whales were widely distributed throughout this area but were typically observed near island complexes, the shelf break, and banks, such as Sanak Bank, Shumagin Bank, and an additional un-named bank, with repeated observations of whales at both Shumagin Bank and the unnamed bank (Brueggeman *et al.* 1987).

Photo-identification data show this area is a destination for whales travelling from breeding areas in Hawaii, Mexico, and Japan (Witteveen *et al.* 2004; Calambokidis *et al.* 2008).

Unit 4 – Central Peninsula Area

The western edge of this area extends along 158° 39' out to the 1,000-m isobath, which forms the offshore boundary. The eastern boundary is at 154° 54' W, just east of the Shumagin Islands. The nearshore boundary of this unit is the 1-m depth contour (relative to MLLW). This unit is within the Lake and Peninsula Borough. Unit 4 covers 15,026 nmi² of marine habitat.

This area captures the waters between two identified feeding BIAs. Survey data indicate that humpback whales are consistently found in these waters (Brueggeman *et al.* 1989, Zerbini *et al.* 2006) and at least occasionally transit between the Shumagin Island area and Kodiak Island (5 of 171 whales; Witteveen *et al.* 2004). Results of systematic surveys conducted in the summers of 2001, 2002, and 2003, indicate that fin whales occurred in high densities in Unit 4, and in particular around the Semidi Islands, relative to the adjacent areas (Units 3 and 5); while humpback whales had the opposite distribution pattern (Zerbini *et al.* 2006). Brueggeman *et al.* (1989) report a fairly similar pattern based on their aerial and shipboard surveys conducted in 1985 and 1987, respectively. Although these two whale species are often sympatric and have overlapping diets, previous surveys and isotope analyses have provided evidence of trophic niche partitioning between fin and humpback whales, with the latter being more piscivorous (Wynne and Witteveen 2013, Gavrilchuk *et al.* 2014, Witteveen *et al.* 2015, Witteveen *et al.* 2016).

Photo-identification data demonstrate that this area is a destination for whales from the HI and MX DPSs (Calambokidis *et al.* 2008).

Unit 5 – Kodiak Island Area

This area includes the waters around Kodiak Island and the Barren Islands. The western boundary runs southward along 154° 54' W to the 1,000-m depth contour, and then extends eastward to a boundary at 150° 40' W. The area also extends northward to the mouth of Cook Inlet where it is bounded by a line that extends from Cape Douglas across the inlet to Cape Adam. The nearshore boundary of this unit is the 1-m depth contour (relative to MLLW). This unit is within the Kodiak Island Borough, but includes a small portion of the Kenai Peninsula Borough. Unit 5 covers 17,420 nmi² of marine habitat.

This area was drawn to capture the Kodiak Island BIA, as well as documented aggregations of humpback whales around the Barren Islands and in waters to the east of Kodiak (Rice and Wolman 1982, Zerbini *et al.* 2006, Ferguson *et al.* 2015a, Rone *et al.* 2017). Waters around Kodiak Islands have been surveyed extensively since 1999 as part of the GAP study. Over 17 years of GAP surveys in this area, 1,187 unique humpback whales were identified in the Kodiak region (out of 2,173 total sightings), with an average annual rate of return of 35% (SD= 15.2%, Witteveen and Wynn 2016), indicating a high degree of site fidelity to this area. Some inter-annual movement of whales has also been observed between this area and lower Cook Inlet and Prince William Sound (Waite *et al.* 1999, Witteveen *et al.* 2011). Waite *et al.* (1999) estimated that only 3%-6% of the Kodiak whales also visit Prince William Sound, and the two areas are viewed as supporting largely separate feeding groups (Waite *et al.* 1999, Witteveen *et al.* 2011). Humpback whales were also historically common in this area and were taken in a commercial whale fishery that operated out of Port Hobron, off the southeastern coast of Kodiak Island (Witteveen *et al.* 2007). While the whales occur throughout this area, they appear to be most abundant off the northeastern and southern coastlines, and are less frequently observed within Shelikof Strait (Zerbini *et al.* 2006). High concentrations of herring, capelin, and eulachon (humpback prey) occur around Kodiak Island (Orsmeth 2014).

Photo-identification data demonstrate this area is a destination for whales from the HI, MX, and WNP DPSs (Calambokidis *et al.* 2008).

Unit 6 – Cook Inlet

This area extends from the mouth of Cook Inlet where it is bounded by a line that extends from Cape Douglas across the inlet to Cape Adam. The northern boundary is the 60° 20' N latitude line, just south of Kalgin Island. The nearshore boundary of this unit is the 1-m depth contour (relative to MLLW). This area borders the Kenai Peninsula Borough. This unit covers 3,366 nmi² of marine habitat.

The southern boundary of this area was drawn to reflect the ecological shift between the Kodiak Island Area (Unit 5) and Cook Inlet. Unit 6 does not include the upper portions of Cook Inlet, because humpback sightings are rare north of Kalgin Island despite extensive, routine aerial surveys of this area for Cook Inlet beluga whales (K. Sheldon, NMML, pers. comm., August 2, 2018). North of the Forelands, the inlet becomes shallow and highly turbid due to deposition of glacial silt. With its extreme tidal range, mudflats, and low visibility, the upper inlet is not likely to provide suitable feeding habitat for humpback whales despite the presence of prey species (e.g., eulachon). Humpback whales are routinely sighted in the lower portions of the inlet (NMML, unpubl. data, 1994-2018), but the density of whales and level of site fidelity of humpback whales to this feeding area has not been established. Inter-annual movements of humpback whales between lower Cook Inlet and the Kodiak Island area (Unit 5) have been observed (Witteveen *et al.* 2011), indicating that the whales feeding in this area do not comprise a completely distinct feeding aggregation.

Photo-identification data demonstrate that HI and MX DPS whales occur in this area (Calambokidis *et al.* 2008).

Unit 7 – Kenai Peninsula Area

This area extends eastward from 150° 40' W at the boundary with Unit 5 (Kodiak Island Area) to 148° 31' W, and extends offshore to the 1,000-m isobath. The nearshore boundary of this unit is the 1-m depth contour (relative to MLLW). This unit is within the Kenai Peninsula Borough. Unit 7 covers 8,496 nmi² of marine habitat.

This area captures the region between the Kodiak Island and Prince William Sound BIAs and includes feeding areas around the Kenai Fjords. Estimated densities of humpback whales within the shelf and slope portion of the Navy's training range, which overlaps with some of Unit 7, has ranged from 0.0930 in 2013 (CV= 0.74) to 0.0050 in 2015 (CV= 0.32, Rone *et al.* 2017). Based on results reported in Witteveen *et al.* 2011, site fidelity of humpback whales to this area can be inferred to be fairly high. Inter-annual movement of whales has also been observed between this area and the coastal waters around Kodiak Island (Witteveen *et al.* 2011).

Photo-identification data demonstrate this area is a destination for whales from the HI and MX DPSs (Calambokidis *et al.* 2008). Satellite telemetry data also indicate this is a destination for MX DPS whales.

A calf tagged off the Revillagigedo Islands in 2003, travelled to the Gulf of Alaska with its mother and spent 30 days feeding on Portlock Bank (located largely within Unit 7) until tracking ceased (Lagerquist *et al.* 2008).

Unit 8 – Prince William Sound Area

This area extends from 148° 31' W eastward to 145° 27' W, and extends offshore to the 1,000-m isobath. The nearshore boundary of this unit is the 1-m depth contour (relative to MLLW). This unit is within the Valdez-Cordova Borough. This unit covers 8,166 nmi² of marine habitat.

This area was drawn to encompass the Prince William Sound feeding BIA (Ferguson *et al.* 2015a), which was identified based on vessel and photo-identification studies conducted mainly in the western and southern portions of the sound (e.g., von Ziegesar *et al.* 2001, Rice *et al.* 2011). The BIA encompasses the portion of this unit where humpback whale densities have been documented to be high and where feeding aggregations have been consistently observed. Survey effort has been very limited in the areas outside of the BIA, especially the shelf waters. This unit was drawn to include waters beyond the boundaries of the BIA based on the additional sightings reported in Witteveen *et al.* (2011, and as detected during SPLASH surveys) and observations reported by von Ziegesar (2013) indicating that humpback whales move between the sound and the fiords along the coast. Minor aggregations of humpback whales (8-13 whales) were also observed near Middleton Island during systematic surveys conducted in summer, 1980 in the Gulf of Alaska (Rice and Wolman 1982). Humpback whales occur year-round in Prince William Sound, but abundance is greatest during spring and fall, and declines in late December to early January (Moran and Straley 2018, Straley *et al.* 2018). Presence of humpback whales in the sound is strongly associated with the seasonal formation of Pacific herring aggregations (Rice *et al.* 2011, Straley *et al.* 2018, Moran and Straley 2018). Results of surveys conducted during fall/ winter of 2007-2009 indicated that a small percentage of photo-identified whales (under 2%, n= 4) overwintered in the sound (Rice *et al.* 2011). Inter-annual movements of whales have been observed between the sound and the coastal waters around Kodiak Island (Waite *et al.* 1999, Witteveen *et al.* 2011). However, Waite *et al.* (1999) estimated that only 3%-6% of the Kodiak whales also visit Prince William Sound, and the two areas are thought to support largely separate feeding groups (Waite *et al.* 1999, Witteveen *et al.* 2011).

Photo-identification data confirm this area is a destination for whales from the HI and MX DPSs (Baker *et al.* 1986, Calambokidis *et al.* 2008). (von Ziegesar (2013) mentions that, as part of SPLASH surveys conducted in 2004 and 2005, one whale that had been photo-identified in the Northern Gulf of Alaska was re-sighted off of Japan and includes a figure that appears to imply this whale was seen within Prince William Sound (see Figure 14 in von Ziegesar (2013)); however, it is not explicitly stated, nor is it reported elsewhere, that this whale was actually sighted within Prince William Sound.)

Unit 9 – Northeastern Gulf of Alaska

This area extends from 145° 27' W to 139° 24' W and offshore to the 1,000-m depth contour. The

nearshore boundary of this unit is the 1-m depth contour (relative to MLLW). This unit mainly borders Yakutat Borough, but also borders a small portion of Valdez-Cordova. Unit 9 covers 9,065 nmi² of marine habitat.

This area was drawn to capture the portion of the Gulf of Alaska between two feeding BIAs (in Units 8 and 10). Surveys within this unit have been relatively limited. Surveys conducted in June -August of 1980 by Rice and Wolman (1982) indicated that humpback whales were sparsely distributed in the Gulf of Alaska (populations were still depleted), but they noted minor aggregations of humpback whales in Yakutat Bay (13 whales). More recently, 21 groups (33 individuals) of humpbacks were sighted in this area during an IWC-POWER cruise in July/August of 2012 (Matsuoka *et al.* 2013). (Fin and sei whales were the most frequently sighted large whales during this cruise, with 210 and 87 individuals sighted, respectively.) Sightings of humpback whales were also recorded in this area by the NMFS SWFSC as part of the SPLASH surveys in 2004 and 2005 (Calambokidis *et al.* 2008; see also Witteveen *et al.* 2011).

Photo-identification data confirm this area is a destination for whales from the HI DPS (Baker *et al.* 1986, Calambokidis *et al.* 2008; and SPLASH data courtesy of C. Gabriele, NPS). Satellite telemetry data indicate this area is also a destination for MX DPS whales: a calf tagged off Socorro Island (in Revillagigedo Archipelago) in 2003 travelled with its mother to this area (Lagerquist *et al.* 2008). (The mother/ calf pair remained in this area for only about 4 days before travelling to other areas of Alaska (Lagerquist *et al.* 2008).)

Unit 10 – Southeastern Alaska

This area extends from 139° 24' W, southeastward to the U.S. border with Canada. The area also extends offshore to the 2,000-m depth contour. The nearshore boundary of this unit corresponds to the BIA boundary. This unit borders unorganized boroughs, but includes water off of Skagway-Hoonah-Angoon, Haines, Juneau, Sitka, Petersburg, Wrangell, and Ketchikan Gateway. Unit 10 covers 22,152 nmi² of marine habitat.

This area was drawn to encompass well established feeding grounds in southeast Alaska and an identified feeding BIA (Andrews 1909, Baker *et al.* 1985, Straley 1990, Dahlheim *et al.* 2009, Ferguson *et al.* 2015a). Humpback whales occur year-round in this unit, with highest densities occurring in summer and fall (Baker *et al.* 1985, 1986). Periods of occupancy of over 100 days have been reported for a significant portion of the whales using this area (Baker *et al.* 1985). Based on sighting data for summer months during 1985 – 2014 in Glacier Bay and Icy Strait, over 60% of the adult whales remained in this area to feed for more than 20 days, and mean residency time for whales seen on more than 1 day within a season was 67 days (SD= 38.3; Gabriele *et al.* 2017). Photo-identification data collected in Southeast Alaska from 1979 to 1983 indicate a high degree of site fidelity to this area, with 47.2 % of whales being sighted in more than one year (154 whales out of 326 unique individuals; Baker *et al.* 1986). Sighting histories for three female humpback whales in particular indicate these whales returned in each of 12 or 13 years during 1977-1992 (Straley *et al.* 1994). Evaluation of sighting histories in Glacier Bay and portions of Icy Strait from 1985 to 2013 also indicate a high degree of site fidelity with 63% (244 of 386

total whales identified) of non-calves returning to the survey area in more than 1-year, 17% (n= 66) returning every year, and an additional 10% (n= 39) missing in only 1 year (Gabriele *et al.* 2017). Recapture histories of humpback whales modeled from photographic data collected from June to September during 1994 - 2008 also indicate a high degree of site fidelity of whales to more specific locations within Unit 10 (Hendrix *et al.* 2012). Humpback whales are known to feed on krill, herring, capelin, sand lance, myctophids, and juvenile pollock within Southeast Alaska, but dominant prey within the diet vary among the specific locations and seasons (Bryant *et al.* 1981, Straley *et al.* 2018).

Photo-identification data confirm this area is a destination for whales from the HI and MX DPSs (Baker *et al.* 1985, 1986; Calambokidis *et al.* 2008).

Unit 11 – Coastal Washington

This area extends southward from the U.S. EEZ to 46° 50' N, just north of Willapa Bay, WA. The unit extends offshore to the 1,200 meter depth contour line, which forms the seaward boundary. The unit includes waters within the U.S. portion of the Strait of Juan de Fuca to an eastern boundary line at Angeles Point (123° 33' W). The 50-m isobath forms the shoreward boundary. The unit includes waters off Clallam and Jefferson Counties, and a portion of Grays Harbor County. Unit 11 covers 3,441 nmi² of marine habitat.

This area was drawn to encompass the Northern Washington BIA (Calambokidis *et al.* 2015), located at the northern edge of this unit, and cells containing the highest 90% of the study area abundance predicted by the Becker *et al.* (2016) habitat model. The BIA typically supports humpback whale feeding aggregations from May to November. In addition to the habitat model results, clusters of humpback whale sightings just off Grays Harbor area (see Calambokidis *et al.* 2015) and movement data collected from five humpback whales with LIMPET satellite tags (Schorr *et al.* 2013) supported inclusion of waters beyond the BIA in this unit. The unit also includes waters within the Strait of Juan de Fuca where whales have been observed foraging in recent years (and which falls outside of the area covered by surveys used to generate the habitat model predictions). Although humpback whales have been increasingly observed within the Salish Sea (Calambokidis *et al.* 2017), Unit 11 does not extend beyond the strait farther into the Salish Sea. High reporting rates from areas within the Salish Sea are likely resulting in a biased understanding of humpback whale abundance in these waters; however, hundreds of whales appear to be using the strait (J. Calambokidis pers. comm., May 23, 2018). The offshore boundary for Unit 11 was selected to follow the contour of cells containing the highest 90% of the study area abundance predicted by the Becker *et al.* (2016) habitat model, which generally coincided with the 1,200-m isobath. Multiple, persistent, dense aggregations (hotspots) of krill (humpback prey) occur near the Juan de Fuca canyon in this area, likely due to the canyon feature (Santora *et al.* 2018). Humpback whales have also been shown to associate with the shelf edge particularly near submarine canyons off Washington (Green *et al.* 1992).

Photo-identification data confirm this area is a destination for whales from the HI, MX, and Central

America (CAM) DPSs (Calambokidis *et al.* 2008).

Unit 12 – Columbia River Area

This area extends southward from 46° 50' N to 45° 10' N and extends out to the 1,200-m depth contour line, which forms the seaward boundary. The 50-m isobath forms the shoreward boundary. This area includes waters off of Pacific County, WA and Clatsop County, OR. This unit covers 3,636 nmi² of marine habitat.

This unit was drawn to capture the Columbia River plume system, which supports foraging by many predators, including concentrations of humpback whales (D. Palacios, OSU, unpublished data). The unit extends both north and south of the mouth of the Columbia River to capture the spatial variation of the plume system. Within this unit, as well as others along the West Coast, hotspots with persistent, heightened abundance of krill also occur in association with submarine canyons (Santora *et al.* 2018). The area boundaries also encompass ARS areas generated from satellite telemetry data (ARS, D. Palacios, unpublished data; Mate *et al.* 2018). The area extends out to the 1,200-m depth contour to capture the outer edge of cells containing the highest 90% of the study area abundance predicted by the Becker *et al.* (2016) habitat model. The southern boundary at 45° 10' N was drawn to encompass ARS areas and to reflect where the habitat model predictions begin to shift farther offshore.

Photo-identification data are not available to validate occurrences of particular DPSs within this unit; however, the available data suggest this area is a destination for whales from the MX and CAM DPSs (Calambokidis *et al.* 2000).

Unit 13 – Coastal Oregon

This area extends southward from 45° 10' latitude to 42° 10', and extends offshore to the 1,200-m isobath. The 50-m isobath forms the shoreward boundary. This area includes the BIA at Stonewall and Heceta Bay, and includes waters off of Tillamook, Lincoln, Lane, Douglas, Coos, and Curry Counties. Unit 13 covers 5,749 nmi² of marine habitat.

This unit includes the Stonewall and Heceta Bank BIA, which supports humpback whale feeding aggregations from May to November (Calambokidis *et al.* 2015). The northern and offshore boundaries of this unit correspond to cells containing the highest 90% of the study area abundance predicted by the Becker *et al.* (2016) habitat model. The predicted abundance begins to extend farther offshore in this area. Within the southern portion of this unit, there is some disagreement between the habitat model predictions (Becker *et al.* 2016) and ARS ranges (D. Palacios, OSU, unpublished data; Mate *et al.* 2018) in terms of the seaward extent of the feeding area. Specifically, the ARS range areas (for polygons representing three or more foraging whales) extends farther offshore than the model predictions. However, because the ARS data were limited to only a small southern portion of this unit, the offshore boundary (1,200-m isobath) was selected to align with the habitat model (which is also based on significantly more humpback whale location data relative to the ARS data). The southern boundary of

this unit was drawn just north of another BIA. Based on surveys conducted in spring and summer of 2000 as part of the US Global Ocean Ecosystem Dynamics (GLOBEC) Northeast Pacific program, concentrations of humpback whales on Heceta Bank were shown to correspond to high densities of fish (Pacific sardine and juvenile salmon) and large, high density patches of krill (Tynan *et al.* 2005, Ressler *et al.* 2005). Within this unit, large, persistent aggregations of krill have been observed inshore of Heceta Bank, off Cape Blanco, in association with submarine canyons (Ressler *et al.* 2005, Santora *et al.* 2018).

Photo-identification data confirm this area is a destination for whales from the MX DPS (Calambokidis *et al.* 2008).

Unit 14 – Southern Oregon/Northern California

This area is bounded in the north at 42° 10' and extends south to the Mendocino escarpment at 40° 20'. The area extends offshore to the 2,000-m isobath. The 50-m isobath forms the shoreward boundary. The area includes the marine waters off Del Norte County, CA, and most of Humboldt County, CA, and borders a small portion of Curry County, OR. Unit 14 covers 3,412 nmi² of marine habitat.

This unit includes the Point St. George BIA, which typically supports whale feeding aggregations during July - November (Calambokidis *et al.* 2015). The northern boundary of this unit corresponds to the boundary of this BIA. The southern boundary corresponds with the Cape Mendocino/the Mendocino escarpment, where the predicted abundance from the habitat model shows a somewhat abrupt shift offshore (Becker *et al.* 2016). The seaward boundary for this unit extends out to the 2,000-m isobath to capture the habitat model predictions. ARS areas derived from satellite tracking data (n = 26 whales, D. Palacios, OSU, unpublished data; Mate *et al.* 2018) indicate that feeding behavior occurs throughout this unit, and although some ARS ranges extend seaward of the 2,000-m isobath, the majority of the ARS behavior is captured within the boundaries of this unit. Multiple, recurring, high density aggregations (hotspots) of krill occur off of Cape Mendocino and elsewhere in this unit, in association with submarine canyons (Santora *et al.* 2018).

Photo-identification data confirm this area is a destination for whales from the MX and CAM DPSs (Calambokidis *et al.* 2008).

Unit 15– California North Coast Area

This unit is bounded along its northern edge by the Mendocino escarpment at approximately 40° 20' N and extends southward to 38° 40' N, which corresponds to the approximate southern boundary of an identified BIA. The area extends offshore to the 3,000-m isobath. The 50-m isobath forms the shoreward boundary. This area includes marine waters off the coasts of Humboldt and Mendocino counties, CA. This unit covers 4,898 nmi² of marine habitat.

The northern boundary of this unit corresponds to the Mendocino escarpment and a shift farther offshore in the habitat model predictions (Becker *et al.* 2016). The offshore boundary of this unit extends out to the 3,000-m depth contour to more closely correspond to cells containing the highest

90% of the study area abundance predicted by the Becker *et al.* (2016) habitat model. This boundary is also supported by ARS range data (based on a minimum of 3 or more whales out of 26 total) indicating that whales are feeding farther from shore (D. Palacios, OSU, unpublished data; Mate *et al.* 2018). This unit also encompasses a BIA that extends from Fort Bragg to Point Arena and that typically supports feeding aggregations of humpback whales from July to November (Calambokidis *et al.* 2015). The southern boundary of the unit corresponds to the northern boundary of another BIA. High-density, persistent aggregations of krill occur off Cape Mendocino and in association with canyon features within this unit (Santora *et al.* 2018). Krill hotspots, measuring about 216 - 320 km², have also been documented offshore of Point Arena near the 2,000-m isobath (Santora *et al.* 2011, Dorman *et al.* 2015).

Photo-identification data are not available to validate occurrences of particular DPSs within this unit; however, the available data strongly suggest this area is a destination for whales from the MX and CAM DPSs (Calambokidis *et al.* 2000).

Unit 16– San Francisco and Monterey Bay Area

This area extends from 38° 40' N southward to 36° 00' N to encompass a BIA. The seaward boundary is defined by the 3,700-m isobath. The inshore boundary is mainly defined by the 15-m isobath, but also extends up to the Golden Gate Bridge within San Francisco Bay. This area includes waters off of the southern edge of Mendocino County, and Sonoma, Marin, San Francisco, San Mateo, Santa Cruz, and Monterey counties. Unit 16 covers 12,349 nmi² of marine habitat.

This unit encompasses the Gulf of the Farallones-Monterey Bay BIA (Calambokidis *et al.* 2015) as well as cells containing the highest 90% of the study area abundance predicted by the Becker *et al.* (2016) habitat model, which was based on humpback whale distributions in warmer months (July-December). In this unit, the habitat model predictions extend farther offshore relative to the more northern West Coast units, and extend even farther offshore when whale distributions in colder months (January- April) are modeled (see Becker *et al.* 2017). Therefore, the offshore boundary was placed at the 3,700-m depth contour to capture areas of higher predicted abundances in both summer and winter. (The area covered by the Becker *et al.* (2017) winter model starts at 38° 00', and we are not aware of any other models based on winter distributions for areas north of this unit.) This area also extends into the mouth of the San Francisco Bay to capture a recently recognized important foraging area for humpback whales (Calambokidis *et al.* 2017) as well as ARS data indicating (based on tracks for 3 or more whales out of a total of 26) that whales are feeding in and around the mouth of the bay (D. Palacios, OSU, unpublished data; Mate *et al.* 2018). The highest densities of whales are seen at the entrance to San Francisco bay with a few extending into the Bay (J. Calambokidis pers. comm., May 23, 2018). Based on data from hydroacoustic surveys spanning multiple years between 2000-2009, persistent and recurring, high-density aggregations of krill ranging in size from about 578 km² to 950 km² have been shown to occur in multiple areas within this unit, including Bodega Head, Cordell Bank, Gulf of the Farallones, Pescadora, and Monterey Bay (Santora *et al.* 2011, Dorman *et al.* 2015, Santora *et al.* 2018).

Photo-identification data confirm this area is a destination for whales from the MX and CAM DPSs

(Baker *et al.* 1986, Calambokidis *et al.* 2008).

Unit 17– Central California Coast Area

This area extends from 36° 00' N to a southern boundary at 34° 30' N, just south of a BIA. The nearshore boundary is defined by the 30-m depth contour, and the seaward boundary is defined by the 3,700-m depth contour. This unit includes waters off of southern Monterey county, and San Luis Obispo and Santa Barbara counties. Unit 17 covers 6,697 nmi² of marine habitat.

This unit encompasses a BIA that extends from Morro Bay to Point Sal and typically supports high density feeding aggregations of humpback whales from April to November (Calambokidis *et al.* 2015). In this area, as with Unit 16, the predicted abundance extends farther offshore in the warmer months (July - December) and even more so in cooler months (January -April) relative to the northern units (Becker *et al.* 2016 and 2017). Therefore, the offshore boundary was placed at the 3,700-m depth contour to capture areas of higher predicted abundance in both summer and winter. The southern boundary for this area was drawn just south of the BIA. Based on acoustic survey data collected during 2004-2009, large krill hotspots, ranging from 700 km² to 2,100 km², occur off Big Sur, San Luis Obispo, and Point Sal (Santora *et al.* 2011). Hotspots with persistent, heightened abundance of krill were also reported in this unit in association with bathymetric submarine canyons (Santora *et al.* 2018).

Photo-identification data confirm this area is a destination for whales from the MX and CAM DPSS (Calambokidis *et al.* 2008).

Unit 18– Channel Islands Area

This area extends from a northern boundary at 34° 30' N to a boundary line that extends from Oxnard, CA seaward to the 3,700-m isobath. The seaward boundary is defined by the 3,700-m depth contour. The 50-m isobath forms the shoreward boundary. This unit includes waters off of Santa Barbara and Ventura counties. This unit covers 9,799 nmi² of marine habitat.

This unit encompasses the Santa Barbara Channel-San Miguel BIA, which supports high density feeding aggregations of humpback whales during March - September (Calambokidis *et al.* 2015). The seaward boundary at the 3,700-m isobath encompasses cells containing the highest 90% of the study area abundance predicted by both the summer and winter habitat models (Becker *et al.* 2016 and 2017). The southern boundary of this unit was selected to correspond to where the habitat model predictions for both models show a clear decline in predicted densities. The area to the south (i.e., Unit 19) is predicted to have much lower summer densities of whales. Based on acoustic survey data collected during 2004 – 2009, a krill hotspot of about 780 km² has been documented off Point Conception (Santora *et al.* 2011). Some additional krill hotspots have also been observed in this unit in association with bathymetric submarine canyons (Santora *et al.* 2018).

Photo-identification data confirm this area is a destination for whales from the MX and CAM DPSS (Calambokidis *et al.* 2008).

Unit 19– California South Coast Area

The northern boundary for this unit extends southwest from Oxnard, CA through the Santa Cruz Basin and out to 3,700-m depth contour. The seaward boundary is defined by the 3,700-m isobath. The unit is also bounded in the south by the U.S. EEZ. The 50-m isobath forms the shoreward boundary. This unit includes waters off of Los Angeles, Orange, and San Diego counties. Unit 19 covers 12,966 nmi² of marine habitat.

This area does not contain a BIA but was added to capture cells containing the highest 90% of the study area abundance predicted by the Becker *et al.* (2017) habitat model. This area falls outside of the predicted high use area in the summer/fall months but is predicted to support high densities of whales in the winter/spring months (Becker *et al.* 2017). The higher densities of humpback whales in winter may stem from the fact that some of the whales sighted in this area may be transiting through the area, rather than occupying the area as a feeding destination. Within this unit, krill hotspots ranging in size from about 210 km² – 430 km² have been observed off San Nicolas and Santa Barbara Islands (Santora *et al.* 2011), and additional hotspots have been observed in association with submarine canyons (Santora *et al.* 2018).

Photo-identification data are not available to validate occurrences of particular DPSs within this unit; however, the available data suggest this area is a destination for whales from the MX and CAM DPSs (Calambokidis *et al.* 2000, Rasmussen *et al.* 2012).

Conservation Value of Specific Areas

Methods

Beginning on September 6, 2018, and through subsequent meetings, the CHRT developed and implemented an approach for evaluating and assigning a conservation value to each specific unit of habitat. To develop a scientific and systematic approach, the CHRT first discussed the categories of available data that should be considered to evaluate the relative conservation value of the critical habitat areas. Once the various datasets were compiled, a subset of the CHRT explored potential methods for applying the data in a systematic way across all habitat units to arrive at a single conservation rating for each habitat unit and for each DPS. Ultimately, based on the results of testing various methods, this smaller group recommended, and the full CHRT agreed, that the best approach was for each member of the team to participate in a structured decision-making process rather than arbitrarily selecting one particular scoring system over another.

To complete this structured decision-making process, the CHRT first reviewed and discussed the compiled, available datasets. These data are described in more detail below and provided in full in Appendix C. After reviewing the datasets as a group, each member of the CHRT independently rated the

habitat unit for each relevant DPS. To do this, each team member distributed four “votes” across the following conservation value categories for each of the critical habitat units:

(1) very high – meaning areas where the available data indicate the area is very important to the conservation of the DPS;

(2) high - meaning areas where the available data indicate the area is important to the conservation of the DPS;

(3) medium - meaning the available data indicate the area is moderately important to the conservation of the DPS; and,

(4) low conservation value - meaning the available data suggest the DPS does not rely on this area for feeding.

All four votes for each unit and for each DPS could be placed in one category or spread across the four categories. The degree to which votes were spread across the conservation value categories thus served as a measure of uncertainty in the conservation value of a particular unit. Because the CHRT consists of 10 team members, each unit of critical habitat received a total of 40 votes (or points). However, CHRT members were permitted to forego assigning their four votes for a specific critical habitat unit if they concluded the available data were either too limited or there was too much uncertainty associated with the available data. In these instances the CHRT members were allowed to instead categorize the unit as “data deficient.” Units receiving “data deficient” votes from one or more CHRT member meant those particular units received less than 40 points.

Following an initial round of scoring, the CHRT met to discuss their assessments of the data and results. Following that team discussion, CHRT members were given the opportunity to independently re-evaluate their own scores and make any changes (*if they elected to do so*). The final conservation ratings for each critical habitat unit, the distribution of votes across the four conservation categories, as well as marks for “data deficient” are provided in Table 3.

The multiple datasets that were considered in this assessment provided information about the level of use of the critical habitat units by humpback whales in general, and the level of use of the units by each particular DPS of the whales (Tables C1-C3). The first dataset contained information about the feeding BIAs that have been identified for humpback whales (see Ferguson *et al.* 2015a, c and Calambokidis *et al.* 2015). Rather than simply considering presence/ absence of a BIA and to make this information equitable across units, we considered the size of the BIAs relative to the size of the particular critical habitat unit. Specifically, we calculated the percent of total area (km²) of a unit that was covered by the BIA within that unit (see Table C4 for calculations). The second dataset included data on the density of humpback whales occurring within each critical habitat unit (regardless of DPS). For units along the West Coast, density of whales was determined using the habitat model results of Becker *et al.* (2016), which allowed for calculations of predicted density within each specific critical habitat unit (predicted abundance / area of the critical habitat unit). (See “Specific Areas” section above for more details about this habitat model.) As no comparable modelling data exist for the habitat units within Alaska (Units 1-

10), whale density information was instead compiled from the most recent, available literature, which covered various years and time periods, and addressed study areas that did not necessarily align with the critical habitat unit boundaries (see Tables C5 and C6 for details). These non-uniform data prevented the CHRT from making any strong inferences about humpback whale densities within Units 1-10 as well as complicated their ability to compare densities across units. The density data pulled from the literature were therefore considered in a very qualitative way and also did not directly determine any votes or conclusions.

A third dataset addressed the presence of whales from each particular DPSs within each critical habitat unit. Three different pieces of information were presented in this dataset. First, using results of the SPLASH study, we calculated the percentage of whales identified to DPS out of all the matched sightings within a specific unit. (Matched sightings are the total number of whales photo-identified in both breeding area and the critical habitat unit. Note that most whales sighted in feeding areas are not from a known DPS.) See Table C7 for total matches and calculations. Secondly, we provided the probabilities of whales from a particular DPS moving from their winter, breeding area to a feeding area (critical habitat unit) as calculated by Wade (2017). These movement probabilities were also derived from SPLASH data. The feeding areas from the SPLASH study and from Wade (2017) represent larger geographic areas than the critical habitat units, so in many cases the same movement probability applied to multiple, adjacent critical habitat units. Lastly, we compiled available documentation of whales from a specific DPS occurring in each unit (i.e., confirmed presence). These data came from both the SPLASH study as well as other references, a complete list of which is provided in Table C8.

The final conservation rating (the “Score” column in Table 3) for each unit and DPS was decided based on the following decision rules. (1) If one category had half or more of the total possible votes, that category was the final rating for that critical habitat unit. (Except in cases where any CHRT members had deemed the area “data deficient,” this would mean having 20+ points in any one category.) (2) For units where no category had half or more of the votes, the category with the greatest number of votes was chosen as the final score, but with a lower degree of certainty. To indicate this greater uncertainty, the score is shown in *italics* in Table 3. (3) For any unit with a tie between two conservation value categories, the final category assigned as being intermediate between the two categories. (For example: unit 12 for the CAM DPS had 18 votes in medium and 18 in low, therefore was given a score of M/L).

Results

Narrative summaries of the conservation rating results are provided below by critical habitat unit. As described above, conservation ratings were assigned by comparing the data for a given DPS across the relevant units of habitat - *and not by comparing data among DPSs*. In other words, the conservation ratings are relative to other areas used by a given DPS and not relative to how other DPSs may use that same area. This approach is appropriate given that critical habitat must be designated independently for each DPS. Final scores for each critical habitat unit by DPS can be found in Table 3; results are also shown in Figure 19 a- c. As noted above, the complete datasets and associated references used in evaluating the habitat units are provided in Appendix C.

Table 3. Conservation value ratings for specific critical habitat areas. Votes from all CHRT members across the four possible conservation value categories (VH = very high, H = high, M = medium, L = low) are shown for each applicable critical habitat unit by DPS. Each of 10 team members was given four votes to apply to the four categories (giving a total of 40 points possible for each unit), or forego voting and mark “data deficient” for a unit. A ✓ in the “data deficient” column indicates that team member(s) deemed the available data too limited or too uncertain to determine the relative conservation value of the habitat unit. (Number of ✓’s corresponds to how many CHRT members selected “data deficient” for the unit). The final conservation rating (i.e., score column) was determined using the category with the majority of votes for each unit (shaded cells). If the category with the greatest number of votes received less than half the total possible votes, the score is shown in *italics* to indicate the greater degree of uncertainty.

(A) Western North Pacific DPS

Unit #	AREA	VH	H	M	L	Data deficient	Score
1	Bristol Bay	15	17	7	1	0	<i>H</i>
2	Aleutian Island Area	33	7	0	0	0	VH
3	Shumagin Islands Area	28	11	1	0	0	VH
4	Central Peninsula Area	0	1	14	21	✓	<i>L</i>
5	Kodiak Island Area	12	13	11	4	0	<i>H</i>
6	Cook Inlet	0	0	6	34	0	<i>L</i>
7	Kenai Peninsula Area	0	2	9	29	0	<i>L</i>
8	Prince William Sound Area	0	4	16	20	0	<i>L</i>
9	Northeastern Gulf of Alaska	1	1	3	27	✓✓	<i>L</i>
10	Southeastern Alaska	0	0	9	27	✓	<i>L</i>

(B) Central America DPS

Unit #	AREA	VH	H	M	L	Data deficient	Score
11	Coastal Washington	8		11	3	0	<i>H</i>
12	Columbia River Area	0	0			✓	M/L
13	Coastal Oregon	0	7		7	0	M
14	Southern Oregon/ Northern California	13		5	0	0	H
15	California North Coast	1	14		7	0	<i>M</i>
16	San Francisco/ Monterey Bay Area		8	1	0	0	VH
17	California Central Coast		4	0	0	0	VH
18	Channel Islands Area	9		9	0	0	H
19	California South Coast Area	0	3	9		0	<i>L</i>

(C) Mexico DPS

Unit #	AREA	VH	H	M	L	Data deficient	Score
1	Bristol Bay	8	13	9	6	✓	H
2	Aleutian Island Area	30	10	0	0	0	VH
3	Shumagin Islands Area	27	13	0	0	0	VH
4	Central Peninsula Area	2	9	23	6	0	M
5	Kodiak Island Area	18	22	0	0	0	H
6	Cook Inlet	2	6	20	12	0	M
7	Kenai Peninsula Area	0	0	16	24	0	L
8	Prince William Sound Area	6	20	13	1	0	H
9	Northeastern Gulf of Alaska	0	1	10	25	✓	L
10	Southeastern Alaska	3	11	19	7	0	M
11	Coastal Washington	18	17	5	0	0	VH
12	Columbia River Area	0	5	21	10	✓	M
13	Coastal Oregon	5	12	21	2	0	M
14	Southern Oregon/ Northern California	19	20	1	0	0	H
15	California North Coast	3	15	19	3	0	M
16	San Francisco/ Monterey Bay Area	37	3	0	0	0	VH
17	California Central Coast	29	11	0	0	0	VH
18	Channel Islands Area	17	18	5	0	0	H
19	California South Coast Area	1	3	10	26	0	L

Unit 1 – Bristol Bay

WNP DPS: High conservation value (17 of 40 votes). Moderate degree of uncertainty, because votes were also cast in all other categories (very high (15 votes), medium (7 votes), and low (1 vote). However, very low degree of uncertainty that this rating is too high, because 15 votes were placed in the very high category

MX DPS: High conservation value (13 of 36 votes). Moderate uncertainty, because remaining votes were spread across all other categories (8 very high votes, 9 medium votes, and 6 low votes). One CHRT member abstained from voting, concluding this unit is “data deficient” for the MX DPS.

Summary: This unit includes a humpback whale feeding BIA that extends over half of the total unit area. There are no reported sightings of photo-identified whales of either DPS in this specific area; however, tagging and genetic data indicate both DPSs occupy this area (Table C8). For example, multiple recoveries of commercially harvested whales that had been marked or tagged indicate connections between the WNP wintering grounds and the Eastern Bering Sea (Omura and Ohsumi 1964, Johnson and

Wolman 1984), and multiple genotype matches of individual whales indicate presence of MX DPS whales within the Eastern Bering Sea (Baker *et al.* 2013). Estimated movement probabilities of whales from both DPSs to this general area are also high (probabilities encompass Units 2 and 3 as well). Reported humpback whales densities in this unit vary widely but some are relatively high.

Unit 2 – Aleutian Island Area

WNP DPS: Very high conservation value (33 of 40 votes), with very low degree of uncertainty (over 80% of the votes were cast in the very high category).

MX DPS: Very high conservation value. Very low degree of uncertainty because this category received 75% of the votes (30 of 40 total). In addition, all remaining 10 votes were placed in in the high value category.

Summary: This unit includes a humpback whale feeding BIA that extends over half of the total unit area. There are confirmed sightings of whales from both the WNP and MX DPSs in this unit, and the estimated probabilities of each DPS moving into this general area are high (i.e., probabilities encompass Units 1 and 3 as well). Results of the SPLASH study indicate that a large percentage of sightings in this unit were of MX DPS whales (35%). Eight percent of the matched sightings were of the WNP DPS, the highest percentage relative to all other units this DPS occurs. (As indicated above, relative abundance of WNP DPS whales is substantially lower than the MX DPS (e.g., 1,066 whales (CV= 0.079) in WNP versus 2,806 whales (CV= 0.055) in the MX DPS; Wade 2017); hence, matched sightings of WNP DPS whales will be generally be more rare.)

Unit 3 – Shumagin Islands Area

WNP DPS: Very high conservation value (28 of 40 votes). Fairly low degree of uncertainty, as 11 votes were cast for high conservation value, 1 for medium, and none for low conservation value.

MX DPS: Very high conservation value (27 of 40 votes). Low degree of uncertainty as this category received about 68% of the votes and all remaining votes were placed in the high category.

Summary: This unit includes a humpback whale feeding BIA that makes up about 30% of the total unit area. There are confirmed sightings of both the WNP and MX DPSs in this unit and high estimated probabilities of movement of each DPS to this general area (i.e., probabilities encompass Units 1 and 3 as well). Results of the SPLASH study indicate that a relatively large percentage of sightings in this area are of the MX DPS (48%, Table C3). Four percent of the matched sightings were of WNP DPS whales, the second highest of any units occupied by this DPS (Table C1).

Unit 4 – Central Peninsula Area

WNP DPS: Low conservation value (21 of 36 votes). Low to moderate degree of uncertainty, as over half the votes assigned to the low category, with 14 additional votes for medium, 1 vote for high, and no votes for very high. One CHRT member indicated this unit was “data deficient” for this DPS.

MX DPS: Medium conservation value (23 of 40 votes). Low to moderate degree of uncertainty, because although the medium category received over half of the votes, remaining votes were distributed across all remaining categories (2 very high, 9 high, and 6 low).

Summary: This unit does not contain a humpback whale BIA, and the reported densities of humpback whales in this unit are relatively low compared to some densities reported elsewhere in Alaska for the same time period (and study, see Table C1). Of three total unique sightings of whales matched to a DPS in this unit during the SPLASH study, one was from the MX DPS (Table C3). There are no reported sightings of photo-identified WNP DPS whales in this specific area; presence has been assumed from photo-identification and genetic data that place WNP DPS whales in this general region of the Gulf of Alaska (Table C8). There is an estimated movement probability of zero for movement of WNP whales from Asia to this general region (Gulf of Alaska), and a very low estimated movement probability (0.004) for whales moving from the Gulf of Alaska to the WNP breeding areas (Wade 2017). Estimated probability of movements to this general area is moderate for the MX DPS.

Unit 5 – Kodiak Island Area

WNP DPS: High conservation value (13 of 40 votes). Moderate degree of uncertainty, as many votes were placed in the very high and medium categories (12 and 11, respectively).

MX DPS: High conservation value (22 of 40 votes). Low degree of uncertainty, as over half of the votes were placed in this category, and all remaining votes were assigned to the very high category (18 votes).

Summary: This unit has a humpback whale feeding BIA that encompasses 21% of the total unit. There are confirmed sightings of both the MX and WNP DPSs in this unit. Of all unique matched sightings recorded during the SPLASH study, 41% are of the MX DPS (Table C3). Fewer than 1% of the matched sightings are of the WNP DPS (which has a substantially smaller estimated population size compared to the MX DPSs). Estimated probability of movements of each DPS to this general area from Wade (2017) are as described above for Unit 4. Reported densities of humpback whales in this unit are relatively high (Tables C1 and C3).

Unit 6 – Cook Inlet

WNP DPS: Low conservation value (34 of 40), with very low degree of uncertainty, as this category received over 75% of the votes and all remaining votes (6) were placed in the same category (medium).

MX DPS: Medium conservation value (20 of 40 votes). Moderate degree of uncertainty, as votes were also placed in all other categories (2 in very high, 6 in high, and 12 in low).

Summary: This unit does not contain a humpback whale BIA. There are no reported sightings of photo-identified WNP DPS whales in this specific area; presence has been assumed based on available data indicating that humpback whales from WNP wintering areas occur in this general region of Alaska (Table C8). There are confirmed sightings of MX DPS whales in this unit, and this DPS makes up 28% of unique

sightings matched to a DPS (out of a total of 18 sightings during the SPLASH study, Table C3). Humpback whale densities in this unit appear to be relatively low. Movement probabilities from Wade (2017) are as described above for Unit 4.

Unit 7 – Kenai Peninsula Area

WNP DPS: Low conservation value (29 of 40 votes). Fairly low degree of uncertainty, as this category received over 70% of the votes and most of the remaining votes (9) were placed in the medium category.

MX DPS: Low conservation value (24 of 40 votes). Fairly low degree of uncertainty, as this category received 60% of the votes, and all remaining votes were placed in the medium category.

Summary: This unit does not contain a humpback whale BIA. There are no reported sightings of photo-identified WNP DPS whales in this specific area. Presence of WNP DPS whales has been assumed based on available data indicating that humpback whales from WNP wintering areas occur within the Gulf of Alaska (Table C8). There are confirmed sightings of MX DPS whales, but of the six unique sightings of whales in this area during the SPLASH study, none were of the MX DPS. The reported humpback whale densities for this unit appear to be relatively low to moderate. Movement probabilities estimated by Wade (2017) are as described above for Unit 4.

Unit 8 – Prince William Sound Area

WNP DPS: Low conservation value (20 of 40 votes). Moderate uncertainty, because a large number of votes (16) were assigned to the medium category, and four votes were placed in the high value category.

MX DPS: High conservation value (20 of 40 votes). Moderate degree of uncertainty due to the spread of votes across all remaining categories (6 in very high, 13 in medium, and 1 in low).

Summary: There is a BIA in this unit, comprising 19% of the total area, and data suggest the density of humpback whales in this unit is relatively high. There are no reported sightings of photo-identified WNP DPS whales in this specific area; however, presence has been assumed based on available data indicating that humpback whales from WNP wintering areas occur in the Gulf of Alaska (Table C8). Photo-identified whales from the MX DPS have been sighted in this unit, and 25% of 12 unique sightings recorded during the SPLASH study are of the MX DPS. See Unit 4 above (or Tables C1 and C3) for information on probability of movement of each DPS to this general area from Wade (2017).

Unit 9 – Northeastern Gulf of Alaska

WNP DPS: Low conservation value. Low degree of uncertainty because 84% of the votes (27 of 32) placed in this category. Two CHRT members concluded this area was “data deficient” due to the lack of information about this DPS in this unit.

MX DPS: Low conservation value. Low to moderate degree of uncertainty, as this category received over half the votes (25 of 40); remaining votes were distributed in medium (10 votes) and high (1 vote). One CHRT member concluded this unit was data deficient for this DPS.

Summary: This unit does not contain a humpback whale BIA. There are no reported sightings of photo-identified whales of the WNP DPS in this specific area; however, presence of these whales has been assumed based on available data suggesting that humpback whales from WNP wintering areas could occur in this general region (Table C8). There are confirmed sightings of the MX DPS in this unit, though the relative predicted probability of movement to this area by the MX DPS is low (Table C3). Movement probabilities for WNP DPS whales into and out of this unit, which overlaps with two of the regions analyzed in Wade (2017), range from very low to zero (Wade 2017). Given the increased distance of this unit from other confirmed sighting of whales from the WNP DPS, there was greater uncertainty regarding whether WNP DPS whales occur in this unit.

Unit 10 – Southeastern Alaska

MX DPS: Medium conservation value (19 of 40 votes). Moderate degree of uncertainty, as this category received fewer than 50% of the votes, and remaining votes were spread across all categories (3 in very high, 11 in high, and 7 in low).

Summary: There is a BIA in Unit 10 that encompasses approximately 45% of the total area of the unit. There are confirmed sightings of MX DPS whales in this unit, including several individuals that have a history of using Unit 10 as part of their feeding range annually for a decade (C. Gabriele, NPS, pers. comm. 5/13/19). Of 235 unique sightings during the SPLASH study, 8.5% were are of the MX DPS; the relative predicted probability of movement to this area by the MX DPS is low for this general area (includes Unit 10 and part of Unit 9; see Table C3).

Unit 11 – Coastal Washington

CAM DPS: High conservation value (18 of 40 votes). Moderate degree of uncertainty, as this category received under 50% of the votes, and remaining votes were spread across the other categories (8 in very high, 11 in medium, and 3 in low).

MX DPS: Very high conservation value (18 of 40 votes). Low to moderate degree of uncertainty, because this category received fewer than 50% of the votes. However, an almost equal number of votes were placed in the high conservation value category (17/40). The remaining five votes were placed in the medium category, and none in low.

Summary: There is a BIA in this unit that covers over 28% of the total area. There are confirmed sightings of both the CAM and MX DPS in this unit (Tables C2 and C3). Out of a total of 19 unique sightings in this area during the SPLASH survey, 68% are from the MX DPS and 5% are of the CAM DPS. (Note the estimated abundance for the CAM DPS (783 whales, CV = 0.170) is substantially lower than for the MX DPS (2,806 whales, CV= 0.055; Wade 2017). Both the MX and CAM DPSs have a relatively small

probability of movement to the larger region (i.e. Southern British Columbia/ Washington) that encompasses Unit 11. The relative predicted density of humpback whales in this unit is moderately high.

Unit 12 – Columbia River Area

CAM DPS: Medium/low conservation value due to a tie in votes between those two categories (18 of 36 votes in each), with one vote abstain due to data deficiency. Moderate uncertainty, because although no other value categories were selected, there was an exact tie between the two categories. One CHRT member concluded the unit was data deficient.

MX DPS: Medium conservation value. Low to moderate degree of uncertainty – although more than half the votes (21 of 36 votes) were placed in this category, remaining votes were placed in both the low category (10 votes) and high categories (5 votes). One CHRT member also selected “data deficient” for this unit.

Summary: This unit does not contain a humpback whale BIA, and the predicted density of humpback whales in this unit is relatively low. There are no reported sightings of photo-identified whales of the CAM DPS in this unit. The estimated probability of movement of CAM DPS whales (over 90%) to this general area is very high; however, this estimated movement probability applies to a large region (includes Units 12 to 19). There are confirmed sightings of the MX DPS in this unit and a moderately high probability of movement of MX DPS whales to this area (but again, this probability applies to a much large area that includes Units 12-19; see Table C3).

Unit 13 – Coastal Oregon

CAM DPS: Medium conservation value based on over half of the votes (26 of 40). Low to moderate degree of uncertainty - although the category received 65% of the votes, some votes were also assigned to high (7) and low (7).

MX DPS: Medium conservation value (21 of 40 votes). Moderate degree of uncertainty. Over half the votes were placed in this category; however, remaining votes were distributed across all other categories (5 very high, 12 high, and 2 low votes).

Summary: A humpback whale feeding BIA extends over 13% of the total area of this unit. There are confirmed sightings or genetic data indicating both the CAM and MX DPSs occur in this unit, but a relatively low predicted density of humpback whales overall. SPLASH results indicate that the one unique humpback whale sighting in this unit of a whale from a specific DPS was a MX DPS whale. The estimated probability of movements is as described above for Unit 12.

Unit 14 – Southern Oregon/Northern California

CAM DPS: High conservation value (22 of 40 votes). Fairly low degree of uncertainty, with most of the remaining votes assigned to very high (13) and relatively few assigned to medium (5).

MX DPS: High conservation value (20 of 40 votes). Low to moderate uncertainty, as an almost equal number of votes were assigned to the very high category (19 of 40). However, there is a low degree of uncertainty that the assigned category is too high given the distribution of votes.

Summary: A humpback whale feeding BIA covers 9.5% of the total unit area. There are confirmed sightings of whales from both the CAM and MX DPSs in this unit; 12.5% of unique SPLASH sightings were from the CAM DPS and 87.5% were from the MX DPS. There is a moderate predicted density of humpback whales for this unit. The estimated probability of movements is as described above for Unit 12.

Unit 15 – California North Coast Area

CAM DPS: Medium conservation value (18 of 40 votes). Moderate degree of uncertainty, as the category received fewer than 50% of the votes and remaining votes were spread across all other categories (1 for very high, 14 for high, and 7 for low).

MX DPS: Medium conservation value (19 of 40 votes). Moderate degree of uncertainty, as the category received fewer than 50% of the votes and remaining votes were spread across all other categories (3 in very high, 15 in high, and 3 in low).

Summary: A humpback whale feeding BIA covers about 9.4% of the total unit area. There are confirmed sightings of CAM and MX DPSs whales in this unit and a moderately high predicted density of humpback whales overall, but no unique sightings from the SPLASH study (Tables C2 and C3). The estimated probability of movements is as described above for Unit 12.

Unit 16 – San Francisco and Monterey Bay Area

CAM DPS: Very high conservation value (31 of 40 votes). Low degree of uncertainty with over 75% of the votes in this category. Most of the remaining votes (8) were in the high value category, and 1 votes was in the medium category.

MX DPS: Very high conservation value (37 of 40 votes). Low degree of uncertainty with over 90% of the votes in this category. The remaining 3 votes were assigned to the high category.

Summary: There is a BIA in this area that encompasses approximately 23% of the total unit area. There are confirmed sightings of CAM and MX DPS whales in this unit. This unit also has the highest predicted density of humpback whales off the U.S. West coast. Of the unique sightings whales during the SPLASH study in this unit, about 15% are from the CAM DPS, and 85% are from the MX DPS (Tables C2 and C3). The estimated probability of movements is as described above for Unit 12.

Unit 17 – Central California Coast Area

CAM DPS: Very high conservation value (36 of 40 votes). Very low degree of uncertainty with 90% of the votes in this category, and all remaining votes were in the high category.

MX DPS: Very high conservation value (29 of 40 votes). Fairly low degree of uncertainty due to about 70% of the votes being assigned to this category, and all remaining votes (11) were assigned to the high conservation value category.

Summary: This unit contains a humpback whale feeding BIA that covers 8% of the unit area. Whales from both the CAM and MX DPSs have been sighted in this area. SPLASH study results indicated that 48% of the unique matched sightings were of CAM DPS whales, and 52% were MX DPS whales (Tables C2 and C3). This unit has the second highest predicted density of humpback whales along the U.S. West coast. The estimated probability of movements is as described above for Unit 12.

Unit 18 – Channel Islands Area

CAM DPS: High conservation value (22 of 40 votes). Fairly low degree of uncertainty, with over 50% of the votes in this category and remaining votes split equally between very high and medium (9 votes each).

MX DPS: High conservation value (18 of 40 votes). Moderate uncertainty level, as fewer than 50% of the votes assigned to this category. However, low degree of uncertainty the assigned category is too high, as 17 votes were assigned to the very high category. The remaining votes (5) were assigned to medium.

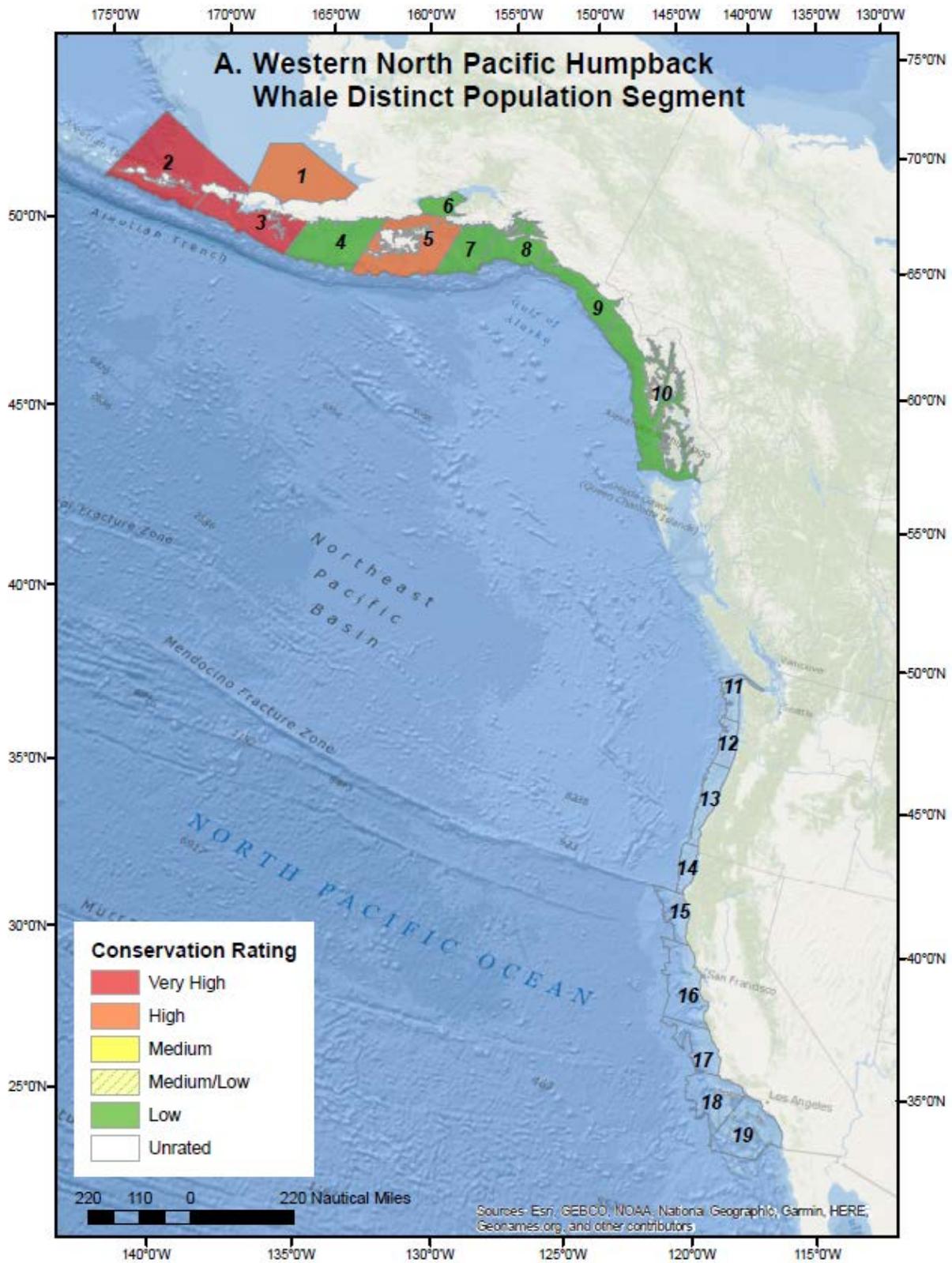
Summary: This unit includes a BIA that covers 7.7% of the total unit area. Whales from both the CAM and MX DPSs have confirmed sightings within this unit, with 24% of the matched unique SPLASH sightings matched to the CAM DPS, and 76% matched to the MX DPS (Tables C2 and C3). The predicted density of humpback whales in this unit is relatively low. The estimated probability of movements is as described above for Unit 12.

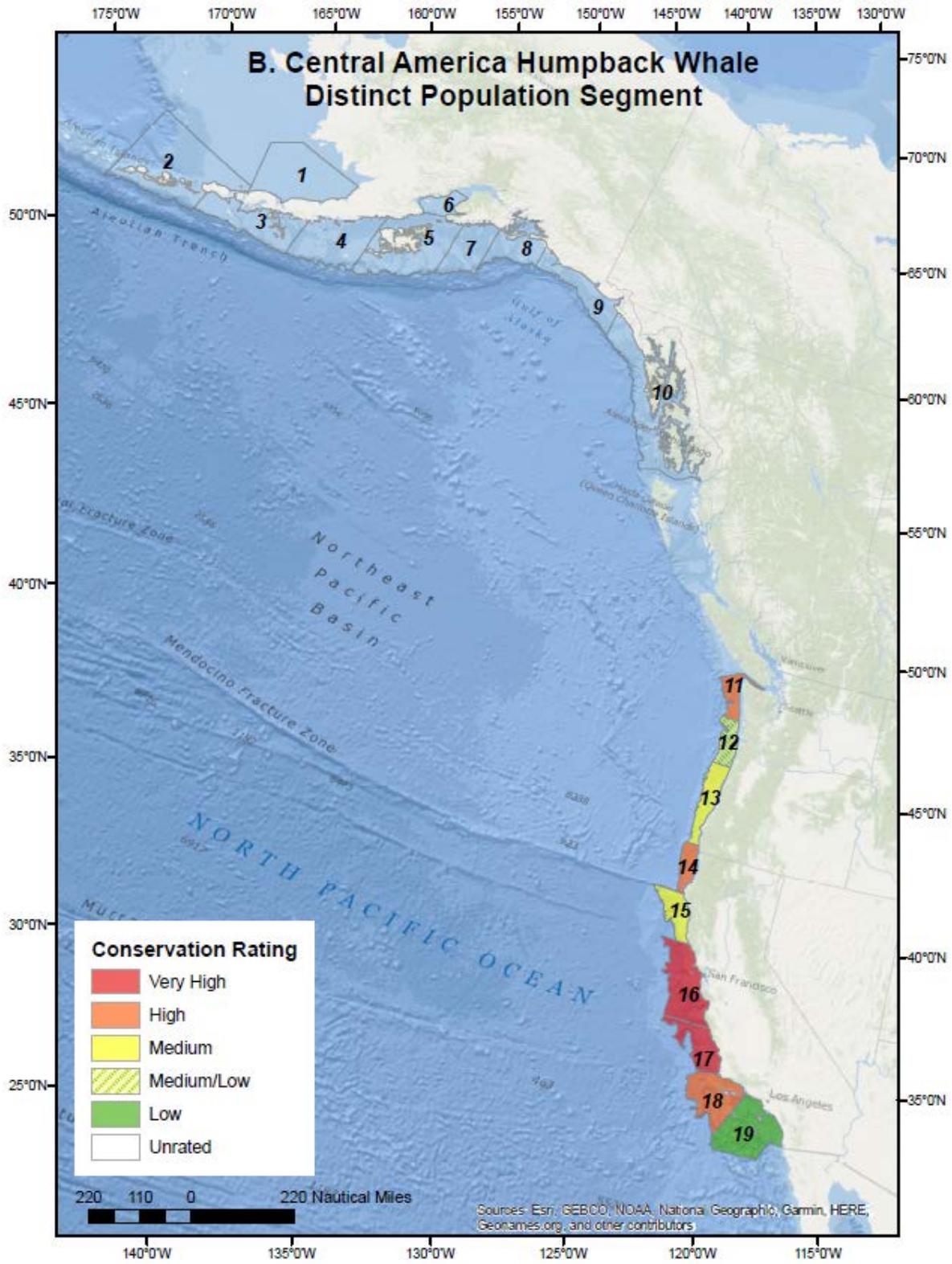
Unit 19 – California South Coast Area

CAM DPS: Low conservation value (28 of 40 votes). Fairly low degree of uncertainty with 70% of the votes assigned to this category and most of the other votes (9) assigned to the medium category. The remaining 3 votes were assigned to the high category.

MX DPS: Low conservation value (26 of 40 votes). Low to moderate degree of uncertainty – although 65% of the votes were placed in this category, remaining votes were spread across all other categories (1 very high, 3 high, and 10 medium).

Summary: This unit does not contain a humpback whale BIA. There are no reported sightings of photo-identified whales of either DPS in this unit, but they are assumed to be in this unit based on what is understood of presence and movement patterns of these whales in other areas along the U.S. West coast (see Table C8). This unit has the lowest predicted density of humpback whales across all U.S. West Coast units (Tables C2 and C3). The estimated probability of movements is as described above for Unit 12.





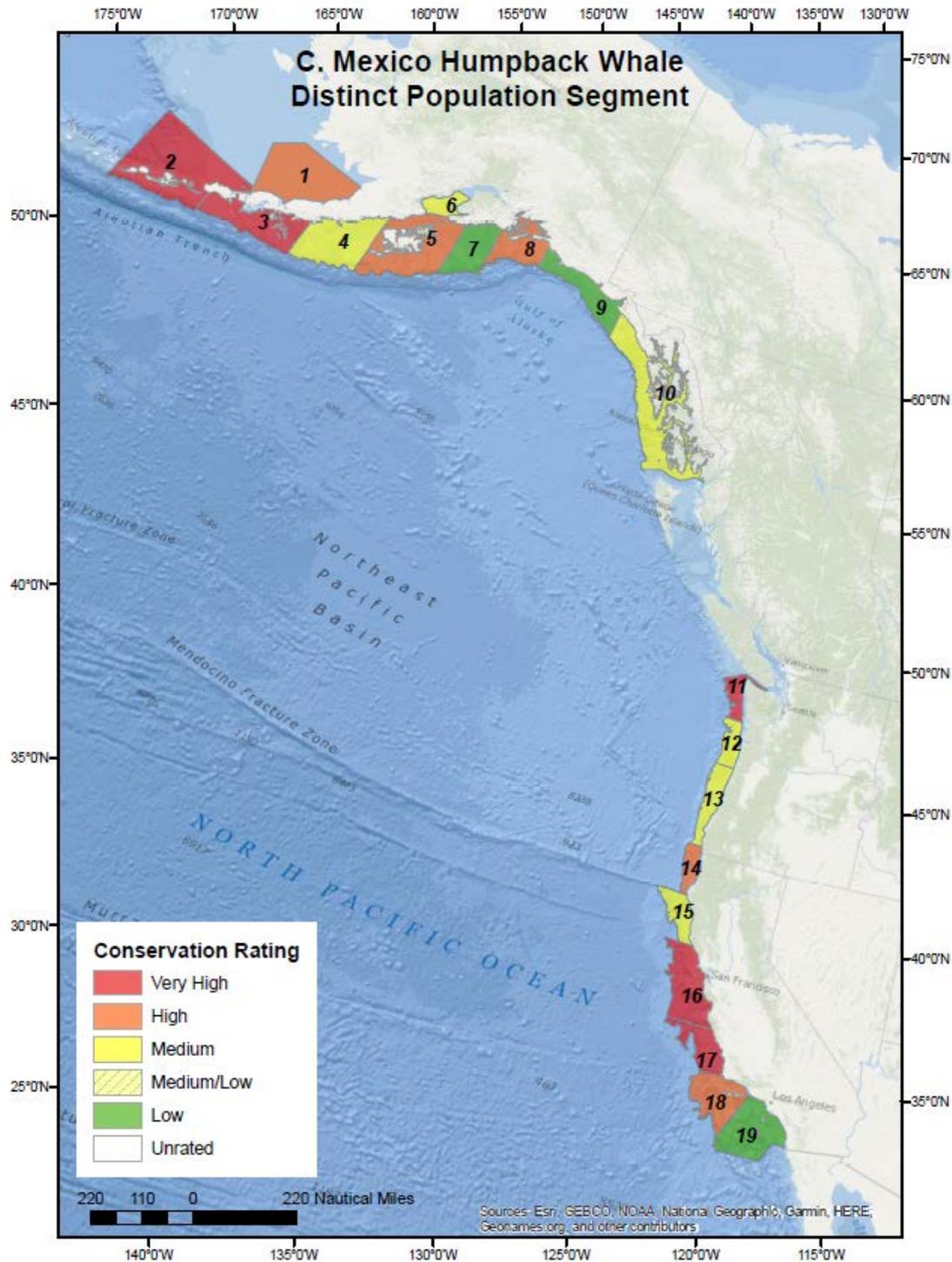


Figure 19. Specific areas of critical habitat and the associated conservation value rating (very high, high, medium, low, or combination) for each DPS: (A) Western North Pacific, (B) Central America, and (C) Mexico. In one instance, a tied rating resulting in the addition of a “Medium/ Low” category.

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Appendix A. Diet information by major feeding region within the North Pacific Ocean

Table A1. Humpback whale diet studies and reported prey for the California Current Ecosystem by prey type and study period.

Prey	Location	Reference	Method	Sampling Year(s)
Euphausiids (<i>Euphausia</i>)	British Columbia, Canada	Andrews 1909	stomach content	1909
Euphausiids (recorded as “shrimp” by whalers, species not given)	Moss landing and Trinidad, California	Clapham <i>et al.</i> 1997	stomach content	1920-1926
Euphausiids (<i>T. spinifera</i> and <i>E. pacifica</i>)	British Columbia, Canada	unpublished data from the Cetacean Research Program, Fisheries and Oceans Canada, cited in Ford <i>et al.</i> 2009	stomach content	1949-1965
Euphausiids (<i>E. pacifica</i>)	Central California	Rice 1963	stomach content	1959-62
Euphausiids (<i>T. spinifera</i> and <i>E. pacifica</i> in fecal and tows, <i>N. simplex</i> and <i>N. difficilis</i> only in tows)	Cordell Bank, California	Kieckhefer 1992	observation of whales feeding on prey and of prey near feeding whales; fecal samples; plankton tows (net)	1988-1990
Euphausiids (species not given)	British Columbia, Canada	unpublished data from the Cetacean Research Program, Fisheries and Oceans Canada, cited in Ford <i>et al.</i> 2009	observation of feeding whales and prey sampling (sampling technique not specified)	2002-2007
Euphausiids (predominately <i>T. spinifera</i> and <i>E. pacifica</i>)	Southern California to Washington Peninsula	Fleming <i>et al.</i> 2016	stable isotope with skin samples	1993-2012
Sardine (<i>Sardinops sagax</i>)	Moss landing and Trinidad, California	Clapham <i>et al.</i> 1997	stomach content	1920-1926
Sardine (<i>Sardinops sagax</i>)	British Columbia, Canada	unpublished data from the Cetacean Research Program, Fisheries and Oceans Canada, cited in Ford <i>et al.</i> 2009	observation of feeding whales and prey sampling (sampling technique not specified)	2002-2007
Sardine (<i>Sardinops sagax</i>)**	Southern California to Washington Peninsula	Fleming <i>et al.</i> 2016	stable isotope with skin samples	1993-2012

Prey	Location	Reference	Method	Sampling Year(s)
Anchovy (<i>Engraulis mordax</i>)	Moss landing and Trinidad, California	Clapham <i>et al.</i> 1997	stomach content	1920-1926
Anchovy (<i>E. mordax</i>)	Central California	Rice 1963	stomach content	1959-62
Anchovy (<i>E. mordax</i>)	Cordell Bank, California	Pers. Comm cited in Kieckhefer 1992	observation of whales feeding on prey and of prey near feeding whales	1988-1990
Anchovy (<i>E. mordax</i>)**	Southern California to Washington Peninsula	Fleming <i>et al.</i> 2016	stable isotope of skin samples	1993-2012
Juvenile rockfish (<i>Sebastes</i> spp.)*	Cordell Bank, California	Kieckhefer 1992	observation of whales feeding on prey and of prey near feeding whales	1988-1990
Herring (<i>Clupea pallasii</i>)	Moss landing and Trinidad, California	Clapham <i>et al.</i> 1997	stomach content	1920-1926
Herring (species not specified)†	California	Thompson 1940	stomach content	1938-1939
Herring (<i>Clupea pallasii</i>)*	Cordell Bank, California	Kieckhefer 1992	observation of whales feeding on prey and of prey near feeding whales	1988-1990
Herring (<i>Clupea pallasii</i>)	British Columbia, Canada	unpublished data from the Cetacean Research Program, Fisheries and Oceans Canada, cited in Ford <i>et al.</i> 2009	observation of feeding whales and prey sampling (sampling technique not specified)	2002-2007
Sand lance (<i>Ammodytes hexapterus</i>)	British Columbia, Canada	unpublished data from the Cetacean Research Program, Fisheries and Oceans Canada, cited in Ford <i>et al.</i> 2009	observation of feeding whales and prey sampling (sampling technique not specified)	2002-2007
Copepods (species not given)	British Columbia, Canada	unpublished data from the Cetacean Research Program, Fisheries and Oceans Canada, cited in Ford <i>et al.</i> 2009	stomach content	1909

*Says in Kieckhefer (1992) that the prey was “tentatively” identified as the species or genus named.

**Analysis suggests these prey species. Stable isotope signatures for anchovy and sardine were similar to that of signatures for humpback whale skin and anchovy abundance correlated with increases in carbon in humpback signatures. Furthermore, sardine and anchovy abundance was correlated. However, isotopic signatures of other fish were not examined. †Thompson 1940 says that the fish remains in stomachs “seem to be those of herring”.

Table A2. Humpback whale diet studies and reported prey for Southeast Alaska (including Glacier Bay, Sitka Sound, and Lynn Canal) and Prince William Sound, by prey type and study period.

Prey	Location	Reference(s)	Methods	Sampling Year(s)
Herring (listed as <i>Clupea harengus</i> ; now known as <i>Clupea pallasii</i>)	Southeast Alaska (Lynn Canal, Frederick Sound, and Glacier Bay)	Jurasz and Jurasz 1979	observation of feeding whales, photographs of prey consumed, prey sampling (plankton tows and fish trawl)	1966-1978
Herring (listed as <i>Clupea harengus pallasii</i> ; now known as <i>Clupea pallasii</i>)	Southeast Alaska (Stephens Passage, Frederick Sound, and Glacier Bay)	Krieger and Wing 1984	observation of feeding whales, acoustic surveys, prey sampling (midwater trawl)	1981-1983
Herring (<i>Clupea pallasii</i>)	Southeast Alaska (Lynn Canal, Sitka Sound)	Rice <i>et al.</i> 2011, Moran <i>et al.</i> 2018	observation of feeding whales, observation of prey near whales, acoustic surveys, prey sampling (nets and tows)	2007-2009
Herring (<i>Clupea pallasii</i>)	Prince William Sound	Moran and Straley 2018 (also see Rice <i>et al.</i> 2011, Moran <i>et al.</i> 2018)	observation, acoustic surveys, stable isotope, prey sampling (plankton tows and nets)	2007-2015
Herring (<i>Clupea pallasii</i>)	Glacier Bay and Icy Strait	Neilson <i>et al.</i> (2017 and 2018)	observations of feeding whales	2016-2018
Euphausiids (<i>Euphuasia pacifica</i>)	Southeast Alaska (Lynn Canal, Frederick Sound, and Glacier Bay)	Jurasz and Jurasz 1979	observation of feeding whales, photographs of prey consumed, prey sampling (plankton tows and fish trawl)	1966-1978
Euphausiids (including <i>T. raschii</i> and <i>E. pacifica</i>)	Southeast Alaska (Stephens Passage, Frederick Sound, and Glacier Bay)	Krieger and Wing 1984	observation of feeding whales, acoustic surveys, prey sampling (midwater trawl)	1981-1983
Euphausiids (species not given)	Southeast Alaska (Sitka Sound)	Rice <i>et al.</i> 2011, Moran <i>et al.</i> 2018	observation of feeding whales, observation of prey near whales, acoustic surveys, prey sampling (nets and tows)	2007-2009
Euphausiids (species not given)	Prince William Sound	Moran and Straley 2018	observation, acoustic surveys, stable isotope, prey sampling (plankton tows and nets)	2007-2015

Prey	Location	Reference(s)	Methods	Sampling Year(s)
Capelin (<i>Mallotus villosus</i>)	Southeast Alaska (Lynn Canal, Frederick Sound, and Glacier Bay)	Jurasz and Jurasz 1979	observation of feeding whales, photographs of prey consumed, prey sampling (plankton tows and fish trawl)	1966-1978
Capelin (<i>Mallotus villosus</i>)	Southeast Alaska (Stephens Passage, Frederick Sound, and Glacier Bay)	Krieger and Wing 1984	observation of feeding whales, acoustic surveys, prey sampling (midwater trawl)	1981-1983
Capelin (<i>Mallotus villosus</i>)	Southeast Alaska (Glacier Bay)	Neilson <i>et al.</i> 2014 and additional NPS reports	observation of feeding whales, prey sampling (dipnet near feeding whales)	Multiple years in 2000s, 2010s
Juvenile walleye pollock (<i>Theragra chalcogramma</i>)	Southeast Alaska (Stephens Passage, Frederick Sound, and Glacier Bay)	Krieger and Wing 1984	observation of feeding whales, acoustic surveys, prey sampling (midwater trawl)	1981-1983
Juvenile walleye pollock (<i>Theragra chalcogramma</i>)	Prince William Sound	Moran and Straley 2018	observation, acoustic surveys, stable isotope, prey sampling (plankton tows and nets)	2007-2015
Myctophids (likely northern lampfish - <i>Stenobrachius leucopsarus</i>)	Southeast Alaska (Icy Strait)	Doherty and Neilson (2002), Neilson and Gabriele (2006, 2008)	observation of feeding whales, prey sampling (dipnet, fish scale id)	2002, 2008
Sand lance (<i>Ammodytes personatus</i>)	Southeast Alaska (Glacier Bay)	Doherty and Gabriele (2002), Neilson and Gabriele (2010), Neilson <i>et al.</i> 2017, Gabriele <i>et al.</i> 2017	observation of feeding whales, prey sampling (dipnet near feeding whales)	Multiple years in 2000s, 2010s
Juvenile coho salmon (<i>O. kisutch</i>)	Prince William Sound	Moran and Straley 2018	observation, acoustic surveys, stable isotope, prey sampling (plankton tows and nets)	2007-2015
Juvenile salmon (<i>O. kisutch</i> , <i>O. keta</i> , <i>O. tshawytscha</i>)	Southeast Alaska	Chenoweth <i>et al.</i> 2017	observation of feeding whales near hatcheries	2010-2015

Table A3. Humpback whale diet studies and reported prey for the Gulf of Alaska and Kodiak region, by prey type and study period.

Prey	Location	Reference(s)	Methods	Sampling year(s)
Capelin (<i>Mallotus villosus</i>)	Kodiak	Witteveen <i>et al.</i> 2006	prey sampling (mid-water trawl)	2001-2002
Capelin (age 1 and >age 1) (<i>Mallotus villosus</i>)	Kodiak	Wright <i>et al.</i> 2016	stable isotope analysis, Bayesian diet modeling	2003-2013
Capelin (age 1 and >age 1) (<i>Mallotus villosus</i>)	Kodiak	Witteveen <i>et al.</i> 2012	stable isotope analysis, Bayesian diet modeling	2004-2006
Capelin (<i>Mallotus villosus</i>)	Kodiak	Witeveen <i>et al.</i> 2008	acoustic surveys, prey sampling (mid-water trawl nets)	2004
Euphausiids (species not given)	Kodiak – Port Hobron	Thompson 1940	stomach contents	1938-39
Euphausiids (<i>Thysanoessa</i> spp.)	Kodiak	Witteveen <i>et al.</i> 2006	prey sampling (mid-water trawl)	2001-2002
Euphausiids (<i>Thysanoessa spinifera</i>)	Kodiak	Wright <i>et al.</i> 2016	stable isotope analysis, Bayesian diet modeling	2003-2013
Euphausiids (<i>Thysanoessa spinifera</i>)	Kodiak	Witteveen <i>et al.</i> 2012	stable isotope analysis, Bayesian diet modeling	2004-2006
Juvenile walleye Pollock (<i>Theragra chalcogramma</i>)	Kodiak	Witteveen <i>et al.</i> 2006	prey sampling (mid-water trawl)	2001-2002
Juvenile walleye pollock (age 0, <i>Theragra chalcogramma</i>)	Kodiak	Wright <i>et al.</i> 2016	stable isotope analysis, Bayesian diet modeling	2003-2013
Juvenile walleye pollock (age 0, <i>Theragra chalcogramma</i>)	Kodiak	Witteveen <i>et al.</i> 2012	stable isotope analysis, Bayesian diet modeling	2004-2006

Prey	Location	Reference(s)	Methods	Sampling year(s)
Juvenile walleye pollock (including age 0, <i>Theragra chalcogramma</i>)	Kodiak	Witteveen <i>et al.</i> 2008	acoustic surveys, prey sampling (mid-water trawl nets)	2004
Sand lance (<i>Ammodytes personatus</i>)	Kodiak	Witteveen <i>et al.</i> 2006	prey sampling (mid-water trawl)	2001-2002
Sand lance (<i>Ammodytes personatus</i>)	Kodiak	Wright <i>et al.</i> 2016	stable isotope analysis, Bayesian diet modeling	2003-2013
Sand lance (<i>Ammodytes personatus</i>)	Kodiak	Witteveen <i>et al.</i> 2012	stable isotope analysis, Bayesian diet modeling	2004-2006
Surf smelt (<i>Hypomesus pretiosus</i>)	Kodiak – Port Hobron	Thompson 1940	stomach contents	1938-39
Copepods (mainly <i>Calanus</i> spp.)	Kodiak – Port Hobron	Thompson 1940	stomach contents	1938-39
Herring (<i>Clupea harengus pallasii</i> now known as <i>Clupea pallasii</i>)	Kodiak	Witteveen <i>et al.</i> 2006	prey sampling (mid-water trawl)	2001-2002
Eulachon (<i>Thaleichthys pacificus</i>)	Kodiak	Witteveen <i>et al.</i> 2006	prey sampling (mid-water trawl)	2001-2002
Eulachon (<i>Thaleichthys pacificus</i>)	Kodiak	Witeveen <i>et al.</i> 2008	acoustic surveys, prey sampling (mid-water trawl nets)	2004
Pacific sandfish (<i>Trichodon trichodon</i>)	Kodiak	Witteveen <i>et al.</i> 2006	prey sampling (mid-water trawl)	2001-2002

Table A4. Humpback whale diet studies and reported prey for the Aleutian Islands and Bering Sea, by prey type and study period. Study locations in the Aleutian Islands/ Bering Sea region include some areas that extend outside of U.S. waters.

Prey	Location	Reference(s)	Methods	Sampling year(s)
Euphausiids (<i>Thysanoessa inermis</i> , <i>T. gregaria</i> , <i>T. spinifera</i>)	Akutan, AK (Aleutian Islands)	Thompson 1940	stomach contents	1938-39
Euphausiids (<i>T. inermis</i> , <i>T. longipes</i> , <i>E. Pacifica</i> , <i>T. spinifera</i>)	Aleutian Islands, Bering Sea	Nemoto 1957,59; Nemoto and Kawamura 1977 (duplicate data)	stomach contents	1952-1958; 1952-1971
Zooplankton (not specified further)	Shumagin Island	Wynne <i>et al.</i> 2013	observation of feeding whales	2010
Atka mackerel (<i>Pleurogrammus monopterygius</i>)	Aleutian Islands, Bering Sea	Nemoto 1957,59	stomach contents	1952-1958
Juvenile walleye pollock (<i>Gadus chalcogrammus</i>)	Aleutian Islands, Bering Sea	Nemoto 1957,59	stomach contents	1952-1958
Capelin (<i>Mallotus catervarius</i> , now known as <i>Mallotus villosus</i>)	Aleutian Islands, Bering Sea	Nemoto 1957,59	stomach contents	1952-1958
Sand lance (<i>Ammodytes personatus</i>)	Aleutian Islands, Bering Sea	Nemoto 1957,59	stomach contents	1952-1958
Pacific cod (<i>Gadus macrocephalus</i>)	Aleutian Islands, Bering Sea	Nemoto 1957	stomach contents	1952-1956

Appendix B. Depth frequency histograms for humpback whale sightings.

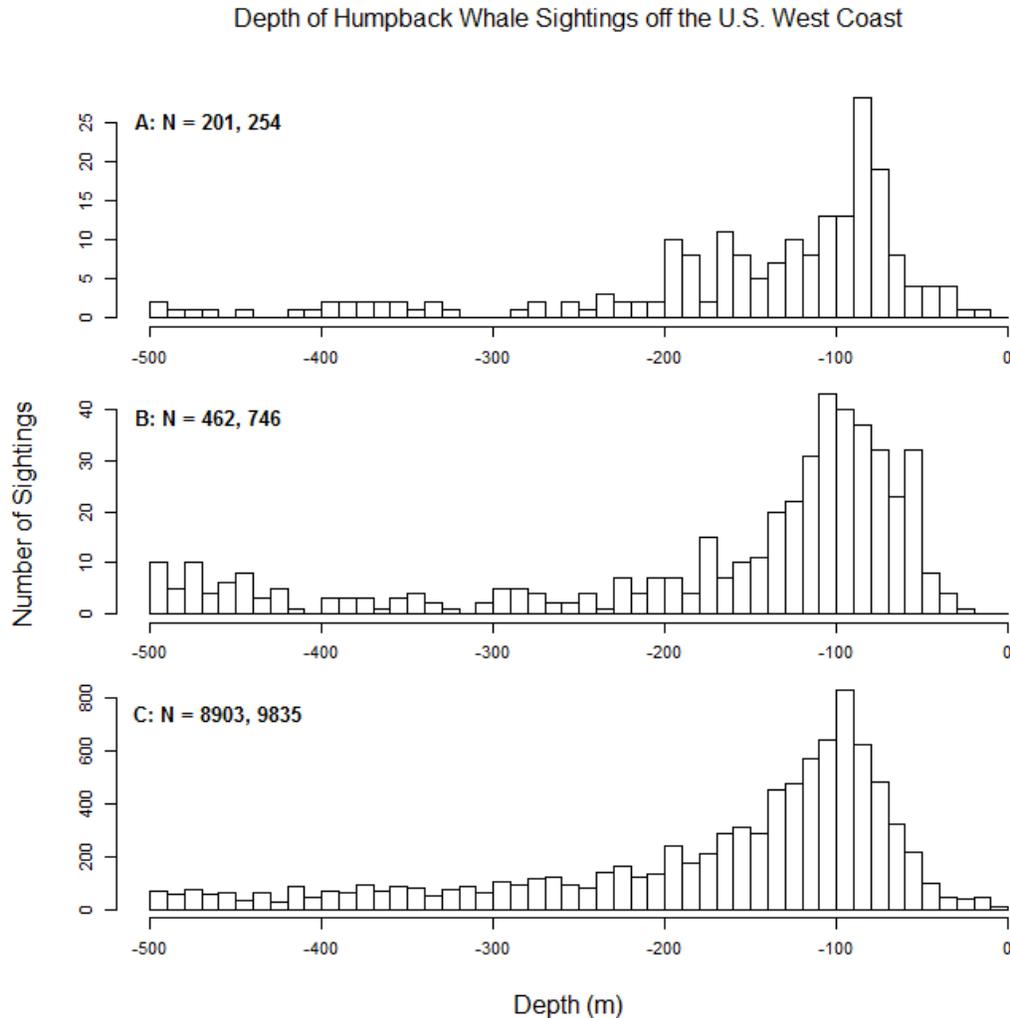


Figure B1. Water depths for locations of humpback whales sightings from multiple surveys (A, B, C) off of the U.S. West Coast (WA, OR, and CA). Histograms show depths of 0 to -500 m only, which captures the peak of the distributions. Sample sizes (N) listed are the number of sightings in the 0 to -500 range and the total number of sightings from the particular data set, respectively. Sources are as follows: (A) humpback whale sightings from SPLASH surveys (compiled by C. Gabriele from Calambokidis *et al.* 2008); (B) sightings from systematic ship surveys conducted by the Southwest Fisheries Science Center between 1991 – 2009 in the CCE (see Becker *et al.* 2016; data courtesy of J. Redfern, SWFSC); (C) sightings from Cascadia surveys (data courtesy of J. Calambokidis).

Depth of Humpback Whale Sightings in Alaska

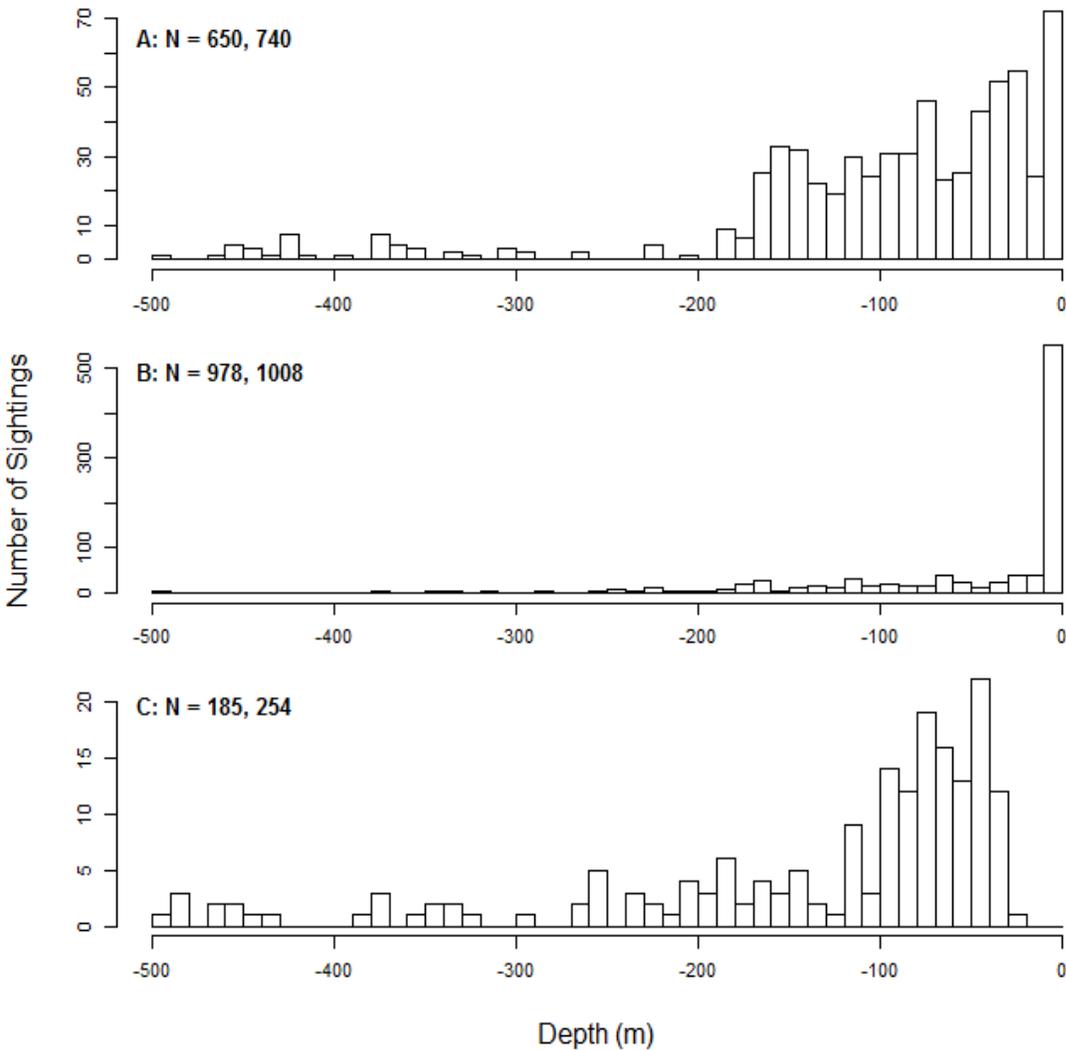


Figure B2. Water depths for locations of sightings of humpback whales from multiple surveys (A, B, C) off of Alaska. Histograms show depths of 0 to -500 m only, which captures the peak of the distributions. Sample sizes (N) listed are the number of sightings in the 0 to -500 range and the total number of sightings from the particular data set, respectively. Sources are as follows: (A) humpback whale sightings documented during surveys conducted by the Alaska Fisheries Science Center along the Central Alaskan coast, including the northern and southern portions of the Central Aleutian Islands, during 2001-2008 and 2009-2010 (see e.g., Zerbini *et al.* 2006; data courtesy of J. Waite, AFSC); (B) SPLASH surveys (compiled by C. Gabriele from Calambokidis *et al.* (2008)); and (C) sightings from marine mammal surveys conducted by the Alaska Fisheries Science Center in the eastern Bering Sea in 1999-2000, 2002, 2004, 2007-2008, and 2010 (PRIEST, Pollock surveys; see e.g., Moore *et al.* 2002, Friday *et al.* 2012, Friday *et al.* 2013, Zerbini *et al.* 2016; data courtesy of J. Waite, AFSC.)

Appendix C. Information used in assessing the conservation value of the specific habitat units for each of the three DPSs.

Table C1. Data compiled and used by the CHRT to inform their assessment of the conservation value of each specific habitat unit occupied by the Western North Pacific DPS (Units 1-9)*. The data provide information on use of the habitat units by humpback whales in general and by whales of the specific DPS. See Tables C4-C8 for more detailed explanations of specific columns.

Western North Pacific DPS		BIAs - % of unit covered by a BIA (see Table C4)		Density per unit of ALL humpback whales, where available. Note: for all densities except those from Becker <i>et al.</i> (2016), reported densities do not correspond 1:1 with the habitat unit (i.e., may be for a smaller area or larger area) and are taken from different studies that applied different methods (see Table C5)		Relative usage of each unit by this DPS based on SPLASH, reported as percent of unique sightings and as movement probabilities as estimated in Wade (2017) (see Table C7)		Confirmed occurrence of the DPS in the unit (see Table C8)
Unit #	Unit	BIAs - Alaska (Ferguson <i>et al.</i> 2015a & c)	BIAs- Washington, Oregon, California (Calambokidis <i>et al.</i> 2015)	Whale density per km ²	Reference (see Table C5)	% unique sightings of the DPS out of all matched sightings (for all DPSs), and total matches for all DPSs in ()	Wade (2017) probability of moving into the unit (Note: larger areas used in the Wade (2017) analysis were aligned to habitat units as best as possible)	WNP DPS occurrence (confirmed sighting)
1	Bristol Bay	56	n/a	0.0288 in 2002, 0.0316 in 2008, 0.0287 in 2010 for coastal area ONLY; 0.0007 in 2008, 0.0032 in 2010 for Middle shelf ONLY; 0.0005 in 2002, 0.0009 in 2008, 0.0004 in 2010 for Outer U.S. portion	Friday <i>et al.</i> 2013	0 (0)	0.946	No

Western North Pacific DPS		BIAs - % of unit covered by a BIA (see Table C4)		Density per unit of ALL humpback whales, where available. <i>Note:</i> for all densities except those from Becker <i>et al.</i> (2016), reported densities do not correspond 1:1 with the habitat unit (i.e., may be for a smaller area or larger area) and are taken from different studies that applied different methods (see Table C5)		Relative usage of each unit by this DPS based on SPLASH, reported as percent of unique sightings and as movement probabilities as estimated in Wade (2017) (see Table C7)		Confirmed occurrence of the DPS in the unit (see Table C8)
Unit #	Unit	BIAs - Alaska (Ferguson <i>et al.</i> 2015a & c)	BIAs- Washington, Oregon, California (Calambokidis <i>et al.</i> 2015)	Whale density per km ²	Reference (see Table C5)	% unique sightings of the DPS out of all matched sightings (for all DPSs), and total matches for all DPSs in ()	Wade (2017) probability of moving into the unit (Note: larger areas used in the Wade (2017) analysis were aligned to habitat units as best as possible)	WNP DPS occurrence (confirmed sighting)
2	Aleutian Island Area	59	n/a	0.02	Zerbini <i>et al.</i> 2006	7.7922 (77)	0.946	Yes
3	Shumagin Islands Area	30	n/a	0.020, 0.012 (blocks 9, 10)	Zerbini <i>et al.</i> 2006	4.3478 (46)	0.946	Yes
4	Central Peninsula Area	0	n/a	0.004, 0.002 (blocks 7-8)	Zerbini <i>et al.</i> 2006	0 (3)	0.000	No
5	Kodiak Island Area	21	n/a	0.052, 0.046, 0.013, 0.066, 0.061 (blocks 2-6)	Zerbini <i>et al.</i> 2006	0.6061 (165)	0.000	Yes

Western North Pacific DPS		BIAs - % of unit covered by a BIA (see Table C4)		Density per unit of ALL humpback whales, where available. <i>Note:</i> for all densities except those from Becker <i>et al.</i> (2016), reported densities do not correspond 1:1 with the habitat unit (i.e., may be for a smaller area or larger area) and are taken from different studies that applied different methods (see Table C5)		Relative usage of each unit by this DPS based on SPLASH, reported as percent of unique sightings and as movement probabilities as estimated in Wade (2017) (see Table C7)		Confirmed occurrence of the DPS in the unit (see Table C8)
Unit #	Unit	BIAs - Alaska (Ferguson <i>et al.</i> 2015a & c)	BIAs- Washington, Oregon, California (Calambokidis <i>et al.</i> 2015)	Whale density per km ²	Reference (see Table C5)	% unique sightings of the DPS out of all matched sightings (for all DPSs), and total matches for all DPSs in ()	Wade (2017) probability of moving into the unit (Note: larger areas used in the Wade (2017) analysis were aligned to habitat units as best as possible)	WNP DPS occurrence (confirmed sighting)
6	Cook Inlet*	0	n/a	0.000206 (average over last 10 yrs 2007-2016) or 0.000265 (average over all years 1994-2016, missing years)	From K. Shelden, NMML, unpubl. data, 1994-2018	0 (18)	0.000	No
7	Kenai Peninsula Area*	0	n/a	0.002 inner part of area 7 (block 1)	Zerbini <i>et al.</i> 2006	0 (6)	0.000	No
8	Prince William Sound Area*	19	n/a	0.085	No density published or available. Used abundance from Moran and Straley (2018) and divided by area of PWS BIA. This was a small study area, so density is likely high.	0 (12)	0.000	No

Western North Pacific DPS		BIAs - % of unit covered by a BIA (see Table C4)		Density per unit of ALL humpback whales, where available. <i>Note:</i> for all densities except those from Becker <i>et al.</i> (2016), reported densities do not correspond 1:1 with the habitat unit (i.e., may be for a smaller area or larger area) and are taken from different studies that applied different methods (see Table C5)		Relative usage of each unit by this DPS based on SPLASH, reported as percent of unique sightings and as movement probabilities as estimated in Wade (2017) (see Table C7)		Confirmed occurrence of the DPS in the unit (see Table C8)
Unit #	Unit	BIAs - Alaska (Ferguson <i>et al.</i> 2015a & c)	BIAs- Washington, Oregon, California (Calambokidis <i>et al.</i> 2015)	Whale density per km ²	Reference (see Table C5)	% unique sightings of the DPS out of all matched sightings (for all DPSs), and total matches for all DPSs in ()	Wade (2017) probability of moving into the unit (Note: larger areas used in the Wade (2017) analysis were aligned to habitat units as best as possible)	WNP DPS occurrence (confirmed sighting)
9	Northeastern Gulf of Alaska*	0	n/a	n/a	n/a	0 (0)	0.000	No
10	Southeastern Alaska*	44.9	n/a	n/a	n/a	0 (235)	0.000	No

* The CHRT discussed and acknowledged the uncertainty regarding the precise extent of the occupied range of the WNP DPS given the limited surveys and limited data available, and elected to take a precautionary approach by including in their analysis all regions where presence of the WNP DPS has been considered to have at least some probability (i.e., Units 6, 7, 8, 9) – see Barlow *et al.* 2011, Wade *et al.* 2016, and Wade 2017. Portions of Unit 10 have been more extensively surveyed and those data do not indicate that the WNP DPS occurs in Unit 10; however, given sightings of WNP DPS whales in the general areas to either side of this Unit (Kodiak, Alaska and Vancouver Island, British Columbia, e.g., Calambokidis *et al.* 2001), the CHRT elected to further document their assessment of this area by subjecting Unit 10 to this analysis.

Table C2. Data compiled and used by the CHRT to inform their assessment of the conservation value of each critical habitat unit occupied by the Central America DPS (Units 11-19). The data provide information on use of different units by humpback whales in general and by whales of the specific DPS. See Tables C4-C8 for more detailed explanations of specific columns.

Central America DPS		BIAs - % of Unit covered by a BIA (see Table C4)		Density per unit of ALL humpback whales, where available. <i>Note:</i> for all densities except those from Becker <i>et al.</i> (2016), reported densities do not correspond 1:1 with the habitat unit (i.e., may be for a smaller area or larger area) and are taken from different studies that applied different methods (see Table C5)		Relative usage of each unit by this DPS based on SPLASH, reported as percent of unique sightings and as movement probabilities estimated in Wade (2017) (see Table C7)		Confirmed occurrence of the DPS in the unit (see Table C8)
Unit #	Unit	BIAs - Alaska (Ferguson <i>et al.</i> 2015a & c)	BIAs- Washington, Oregon, California (Calambokidis <i>et al.</i> 2015)	Whale density per km ²	Reference (see Table C5)	% unique sightings of the DPS out of all matched sightings (for all DPSs), and total matches for all DPSs in ()	Wade (2017) probability of moving into the unit (Note: larger areas used in the Wade (2017) analysis were aligned to habitat units as best as possible)	CAM DPS occurrence (confirmed sighting)
11	Coastal WA	n/a	28.7	0.0054	Becker <i>et al.</i> (2016)	5.2632 (19)	0.074	Yes
12	Columbia R. Area	n/a	0	0.00396	Becker <i>et al.</i> (2016)	0 (0)	0.926	No
13	Coastal OR	n/a	13	0.0036	Becker <i>et al.</i> (2016)	0 (1)	0.926	Yes
14	S. OR/ N. CA	n/a	9.5	0.00444	Becker <i>et al.</i> (2016)	12.5 (24)	0.926	Yes
15	CA N. Coast	n/a	9.4	0.00538	Becker <i>et al.</i> (2016)	0 (0)	0.926	Yes
16	San Francisco/ Monterey Bay Area	n/a	22.9	0.00866	Becker <i>et al.</i> (2016)	14.6667 (75)	0.926	Yes
17	CA Central Coast	n/a	8	0.00731	Becker <i>et al.</i> (2016)	47.8261 (23)	0.926	Yes
18	Channel Islands Area	n/a	7.7	0.00318	Becker <i>et al.</i> (2016)	24.0 (25)	0.926	Yes
19	CA S.Coast Area	n/a	0	0.00042	Becker <i>et al.</i> (2016)	0 (0)	0.926	No

Table C3. Data compiled and used by the CHRT to inform their assessment of the conservation value of each critical habitat unit occupied by the Mexico DPS (Units 1 -19). The data provide information on use of different units by humpback whales in general and by whales of the specific DPS. See Tables C4-C8 for more detailed explanations of specific columns.

Mexico DPS		BIAs - % of Unit covered by a BIA (see Table C4)		Density per unit of ALL humpback whales, where available. <u>Note:</u> for all densities except those from Becker <i>et al.</i> (2016), reported densities do not correspond 1:1 with the habitat unit (i.e., may be for a smaller area or larger area) and are taken from different studies that applied different methods (see Table C5)		Relative usage of each unit by this DPS based on SPLASH, reported as percent of unique sightings and as movement probabilities estimated in Wade (2017) (see Table C7)		Confirmed occurrence of the DPS in the unit (see Table C8)
Unit #	Unit	BIAs - Alaska (Ferguson <i>et al.</i> 2015a & c)	BIAs- Washington, Oregon, California (Calambokidis <i>et al.</i> 2015)	Whale density per km ²	Reference (see Table C5)	% unique sightings of the DPS out of all matched sightings (for all DPSs), and total matches for all DPSs in ()	Wade (2017) probability of moving into the unit (Note: larger areas used in the Wade (2017) analysis were aligned to habitat units as best as possible)	MX DPS occurrence (confirmed sighting)
1	Bristol Bay	56.2	n/a	0.0288 in 2002, 0.0316 in 2008, 0.0287 in 2010 for coastal area ONLY; 0.0007 in 2008, 0.0032 in 2010 for Middle shelf ONLY; 0.0005 in 2002, 0.0009 in 2008, 0.0004 in 2010 for Outer U.S. portion	Friday <i>et al.</i> 2013	0 (0)	0.552	No

Mexico DPS		BIAs - % of Unit covered by a BIA (see Table C4)		Density per unit of ALL humpback whales, where available. <u>Note:</u> for all densities except those from Becker <i>et al.</i> (2016), reported densities do not correspond 1:1 with the habitat unit (i.e., may be for a smaller area or larger area) and are taken from different studies that applied different methods (see Table C5)		Relative usage of each unit by this DPS based on SPLASH, reported as percent of unique sightings and as movement probabilities estimated in Wade (2017) (see Table C7)		Confirmed occurrence of the DPS in the unit (see Table C8)
Unit #	Unit	BIAs - Alaska (Ferguson <i>et al.</i> 2015a & c)	BIAs- Washington, Oregon, California (Calambokidis <i>et al.</i> 2015)	Whale density per km ²	Reference (see Table C5)	% unique sightings of the DPS out of all matched sightings (for all DPSs), and total matches for all DPSs in ()	Wade (2017) probability of moving into the unit (Note: larger areas used in the Wade (2017) analysis were aligned to habitat units as best as possible)	MX DPS occurrence (confirmed sighting)
2	Aleutian Island Area	59.3	n/a	0.02	Zerbini <i>et al.</i> 2006	35.0649 (77)	0.552	Yes
3	Shumagin Islands Area	30.2	n/a	0.020, 0.012 (blocks 9, 10)	Zerbini <i>et al.</i> 2006	47.8261 (46)	0.552	Yes
4	Central Peninsula Area	0	n/a	0.004, 0.002 (blocks 7-8)	Zerbini <i>et al.</i> 2006	33.3333 (3)	0.111	Yes
5	Kodiak Island Area	21.1	n/a	0.052, 0.046, 0.013, 0.066, 0.061 (blocks 2-6)	Zerbini <i>et al.</i> 2006	41.2121 (165)	0.111	Yes
6	Cook Inlet	0	n/a	0.000206 (average over last 10 yrs 2007-2016) or 0.000265 (average over all years 1994-2016, missing years)	From K. Sheldon, NMML, unpubl. data, 1994-2018	27.7778 (18)	0.111	Yes

Mexico DPS		BIAs - % of Unit covered by a BIA (see Table C4)		Density per unit of ALL humpback whales, where available. <u>Note</u> : for all densities except those from Becker <i>et al.</i> (2016), reported densities do not correspond 1:1 with the habitat unit (i.e., may be for a smaller area or larger area) and are taken from different studies that applied different methods (see Table C5)		Relative usage of each unit by this DPS based on SPLASH, reported as percent of unique sightings and as movement probabilities estimated in Wade (2017) (see Table C7)		Confirmed occurrence of the DPS in the unit (see Table C8)
Unit #	Unit	BIAs - Alaska (Ferguson <i>et al.</i> 2015a & c)	BIAs- Washington, Oregon, California (Calambokidis <i>et al.</i> 2015)	Whale density per km ²	Reference (see Table C5)	% unique sightings of the DPS out of all matched sightings (for all DPSs), and total matches for all DPSs in ()	Wade (2017) probability of moving into the unit (Note: larger areas used in the Wade (2017) analysis were aligned to habitat units as best as possible)	MX DPS occurrence (confirmed sighting)
7	Kenai Peninsula Area	0	n/a	0.002 inner part of area 7 (block 1)	Zerbini <i>et al.</i> 2006	0 (6)	0.111	Yes
8	Prince William Sound Area	19.3	n/a	0.085	No density published or available. Used abundance from Moran and Straley (2018) and divided by area of PWS BIA. This was a small study area, so density is likely high.	25.0 (12)	0.111	Yes
9	Northeastern Gulf of Alaska	0	n/a	n/a	n/a	0 (0)	0.111	Yes
10	Southeastern Alaska	44.9	n/a	n/a	n/a	8.5106 (235)	0.02	Yes
11	Coastal Washington	n/a	28.7	0.0054	Becker <i>et al.</i> (2016)	68.4211 (19)	0.033	Yes

Mexico DPS		BIAs - % of Unit covered by a BIA (see Table C4)		Density per unit of ALL humpback whales, where available. <u>Note:</u> for all densities except those from Becker <i>et al.</i> (2016), reported densities do not correspond 1:1 with the habitat unit (i.e., may be for a smaller area or larger area) and are taken from different studies that applied different methods (see Table C5)		Relative usage of each unit by this DPS based on SPLASH, reported as percent of unique sightings and as movement probabilities estimated in Wade (2017) (see Table C7)		Confirmed occurrence of the DPS in the unit (see Table C8)
Unit #	Unit	BIAs - Alaska (Ferguson <i>et al.</i> 2015a & c)	BIAs- Washington, Oregon, California (Calambokidis <i>et al.</i> 2015)	Whale density per km ²	Reference (see Table C5)	% unique sightings of the DPS out of all matched sightings (for all DPSs), and total matches for all DPSs in ()	Wade (2017) probability of moving into the unit (Note: larger areas used in the Wade (2017) analysis were aligned to habitat units as best as possible)	MX DPS occurrence (confirmed sighting)
12	Columbia River Area	n/a	0	0.00396	Becker <i>et al.</i> (2016)	0 (0)	0.284	Yes
13	Coastal Oregon	n/a	13.0	0.0036	Becker <i>et al.</i> (2016)	100 (1)	0.284	Yes
14	Southern Oregon/ Northern California	n/a	9.5	0.00444	Becker <i>et al.</i> (2016)	87.5 (24)	0.284	Yes
15	California North Coast	n/a	9.4	0.00538	Becker <i>et al.</i> (2016)	0 (0)	0.284	Yes
16	San Francisco/ Monterey Bay Area	n/a	22.9	0.00866	Becker <i>et al.</i> (2016)	85.3333 (75)	0.284	Yes
17	California Central Coast	n/a	8	0.00731	Becker <i>et al.</i> (2016)	52.1739 (23)	0.284	Yes
18	Channel Islands Area	n/a	7.7	0.00318	Becker <i>et al.</i> (2016)	76.0 (25)	0.284	Yes
19	California South Coast Area	n/a	0	0.00042	Becker <i>et al.</i> (2016)	0 (0)	0.284	No

Table C4. Calculations of the percent of each critical habitat unit covered by a BIA, results of which were provided in the data tables (C1-C3) to inform the conservation value ratings of each critical habitat unit.

Unit	BIA Area (km ²)	Reference*	% of total BIA area	Critical habitat unit area (km ²)	% of total critical habitat unit area	%BIA (% of the unit covered by a BIA)
1	37129.79	Ferguson <i>et al.</i> 2015c	20.14%	66123.74	9.27	56.2
2	58667.37	Ferguson <i>et al.</i> 2015c	31.82%	98882.02	13.87	59.3
3	13654.80	Ferguson <i>et al.</i> 2015a	7.41%	45145.18	6.33	30.2
4	NA	Ferguson <i>et al.</i> 2015a	0.00%	51538.22	7.23	0.0
5	12617.20	Ferguson <i>et al.</i> 2015a	6.84%	59749.10	8.38	21.1
6	NA	Ferguson <i>et al.</i> 2015a	0.00%	11545.73	1.62	0.0
7	NA	Ferguson <i>et al.</i> 2015a	0.00%	29138.92	4.09	0.0
8	5416.23	Ferguson <i>et al.</i> 2015a	2.94%	28009.58	3.93	19.3
9	NA	Ferguson <i>et al.</i> 2015a	0.00%	31090.69	4.36	0.0
10	34091.15	Ferguson <i>et al.</i> 2015a	18.49%	75978.65	10.65	44.9
11	3392.89	Calambokidis <i>et al.</i> 2015	1.84%	11801.47	1.65	28.7
12	NA	Calambokidis <i>et al.</i> 2015	0.00%	12471.81	1.75	0.0
13	2572.76	Calambokidis <i>et al.</i> 2015	1.40%	19720.25	2.77	13.0
14	1110.022	Calambokidis <i>et al.</i> 2015	0.60%	11702.65	1.64	9.5
15	1584.07	Calambokidis <i>et al.</i> 2015	0.86%	16801.01	2.36	9.4
16	9681.88	Calambokidis <i>et al.</i> 2015	5.25%	42356.19	5.94	22.9
17	1843.25	Calambokidis <i>et al.</i> 2015	1.00%	22968.56	3.22	8.0
18	2590.71	Calambokidis <i>et al.</i> 2015	1.41%	33608.46	4.71	7.7
19	NA	Calambokidis <i>et al.</i> 2015	0.00%	44473.32	6.24	0.0
Total	184,352.13			713,105.56		
BIA area in AK	161,576.54		Total area in AK	497,202.84		
BIA area in WA/OR/CA	22,775.59		Total area in WA/OR/CA	215,903.72		

* BIAs were drawn differently in Alaska vs. other portions of U.S. West coast (see citations).

Table C5. Description and references for estimates of humpback whale density for each critical habitat unit that were used in density columns for data Tables C1-C3, which were used to inform the conservation value rating of each critical habitat unit. For Units 1-10, density data were taken from the cited references. Study areas were matched to the critical habitat units as best as possible but were not perfectly aligned (i.e., densities were either for areas smaller than critical habitat units or bigger than critical habitat units). Densities for Units 11-19, were calculated using predicted abundance from Becker *et al.* (2016) habitat model within each of the critical habitat units. Data for this model were collected from 1991-2009.

Unit	Unit Name	Density
Alaska		
1	Bristol Bay	0.0288 in 2002, 0.0316 in 2008, 0.0287 in 2010 for coastal area ONLY; 0.0007 in 2008, 0.0032 in 2010 for Middle shelf ONLY; 0.0005 in 2002, 0.0009 in 2008, 0.0004 in 2010 for Outer U.S. portion - From Friday <i>et al.</i> (2013). Calculated for different areas in the Bering Sea - none match unit perfectly and areas contain part of unit 2
2	Aleutian Island Area	0.020 (Zerbini <i>et al.</i> 2006, block 12, km ² = 20214, years 2001-2003)
3	Shumagin Islands Area	0.020, 0.012 (Zerbini <i>et al.</i> 2006, blocks 9-10, km ² = 5487, 28827, years 2001-2003)
4	Central Peninsula Area	0.004, 0.002 (Zerbini <i>et al.</i> 2006, blocks 7-8, km ² = 10250, 14464)
5	Kodiak Island Area	0.052, 0.046, 0.013, 0.066, 0.061 (Zerbini <i>et al.</i> 2006, blocks 2-6, km ² = 3910, 4626, 13190, 9757, 7809; years 2001-2003)
6	Cook Inlet	0.000206 (average over last 10 yrs. 2007-2016) or 0.000265 (average over all years 1994-2016, missing years) - From K. Shelden, NMML, unpubl. data, 1994-2018
7	Kenai Peninsula Area	0.002 inner part of area 7 (Zerbini <i>et al.</i> 2006, block 1, km ² = 9060; years 2001-2003)
8	Prince William Sound Area	0.085 - No density published or available. Used abundance of 461 whales from Moran and Straley (2018; based on mark-recapture with data from 2007-2015) and divided by area of PWS BIA. This was a small study area, so density is likely high.
9	Northeastern Gulf of Alaska	n/a
10	Southeastern Gulf of Alaska	n/a - abundance available but no density

Unit	Unit Name	Density
Washington, Oregon, California		
11	Coastal Washington	0.0054
12	Columbia River Area	0.00396
13	Coastal Oregon	0.0036
14	Southern Oregon/ Northern California	0.00444
15	California North Coast Area	0.00538
16	San Francisco and Monterey Bay Area	0.00866
17	California Central Coast Area	0.00731
18	Channel Islands Area	0.00318
19	California South Coast Area	0.00042

Table C6. Geographic comparison of Zerbini *et al.* (2006) density blocks to critical habitat units. Results used to roughly approximate density per critical habitat unit as applied in Table C5.

Block	Density in block (total area km²) from Zerbini <i>et al.</i> (2006)	Humpback whale critical habitat unit (approximate)
1	0.002 (9060)	7
2	0.052 (3910)	5
3	0.046 (4926)	5
4	0.013 (13190)	5
5	0.066 (9757)	5
6	0.061 (7809)	4, 5 (mainly 5, added to 5)
7	0.004 (10250)	4
8	0.002 (14464)	4, 5 (mainly 4, added to 4)
9	0.020 (5487)	3, 4
10	0.012 (28827)	3
11	Density not provided. Sightings in area	2
12	0.020 (20214)	2
13	0.004 (16547)	outside

Table C7. Total matched sightings and percentage of unique sightings of whales of each DPS by critical habitat unit. This table shows - of all matched sightings (i.e., whales of *any* DPS photo-identified in both a breeding area and in a feeding unit) - how many of the matched sightings occurring in that unit are of each specific DPS. The percentages for each DPS appear in Tables C1-C3 and were used to inform voting on the conservation value rating of the critical habitat units. Photo-identification data are from the SPLASH study (e.g., Calambokidis *et al.* 2008).

Percent of Unique Sightings							
Unit	total matched sightings for ALL whales	WNP sightings	% WNP sightings of total matched sightings	MX sightings	% MX sightings of total matched sightings	CAM sightings	% CAM sightings of total matched sightings
1	0	0	0	0	0	0	0
2	77	6	7.8	27	35.1	0	0
3	46	2	4.3	22	47.8	0	0
4	3	0	0	1	33.3	0	0
5	165	1	0.6	68	41.2	0	0
6	18	0	0	5	27.8	0	0
7	6	0	0	0	0	0	0
8	12	0	0	3	25.0	0	0
9	0	0	0	0	0	0	0
10	235	0	0	20	8.5	0	0
11	19	0	0	13	68.4	1	5.3
12	0	0	0	0	0	0	0
13	1	0	0	1	100	0	0
14	24	0	0	21	87.5	3	12.5
15	0	0	0	0	0	0	0
16	75	0	0	64	85.3	11	14.7
17	23	0	0	12	52.2	11	47.8
18	25	0	0	19	76.0	6	24.0
19	0	0	0	0	0	0	0

Table C8. Presence of whales from each DPSs within each of the 19 specific habitat units. MX = Mexico DPS, WNP = Western North Pacific DPS, and CAM = Central America DPS. Documentation of confirmed occurrence of DPSs is through photo-identification, genetic analysis, satellite tracking, or combinations of these. DPS names are **bolded** if the DPS has been confirmed to occur in the specific unit. “SPLASH” is noted as the reference for photo-identification matching of whales between breeding and foraging areas, linking DPSs to foraging areas (raw sightings data provided by C. Gabriele, NPS). Where DPS names are not bolded, the DPS is assumed to occur in that unit based on sightings in a broader region, genetic data that applies to a broader region, or modeling of existing sighting data.

Unit	Unit Name	DPS	References for confirmed (bold) or assumed (non-bold) DPS presence in a unit
1	Bristol Bay	MX WNP	Omura and Ohsumi (1964) (WNP), Johnson and Wolman (1984), Calambokidis <i>et al.</i> (2008), Barlow <i>et al.</i> (2011), Baker <i>et al.</i> (2013)* (MX), Wade <i>et al.</i> (2016)
2	Aleutian Island Area	MX WNP	Omura and Ohsumi (1964) (WNP), Ohsumi and Masaki (1975) (WNP), SPLASH Calambokidis <i>et al.</i> (2008), Barlow <i>et al.</i> (2011), Baker <i>et al.</i> (2013)* (MX), Wade <i>et al.</i> (2016)
3	Shumagin Islands Area	MX WNP	Calambokidis <i>et al.</i> (1997), Witteveen <i>et al.</i> 2004, SPLASH Calambokidis <i>et al.</i> (2008), Barlow <i>et al.</i> (2011), Baker <i>et al.</i> (2013)* (MX), Wade <i>et al.</i> (2016)
4	Central Peninsula Area	MX WNP	SPLASH Calambokidis <i>et al.</i> (2008), Barlow <i>et al.</i> (2011), Baker <i>et al.</i> (2013)*, Wade <i>et al.</i> (2016)
5	Kodiak Island Area	MX WNP	Calambokidis <i>et al.</i> (1997), SPLASH Calambokidis <i>et al.</i> (2008), Barlow <i>et al.</i> (2011), Baker <i>et al.</i> (2013)*, Wade <i>et al.</i> (2016)
6	Cook Inlet	MX WNP	SPLASH Calambokidis <i>et al.</i> (2008), Barlow <i>et al.</i> (2011), Baker <i>et al.</i> (2013)* (MX), Wade <i>et al.</i> (2016)
7	Kenai Peninsula Area	MX WNP	SPLASH, Lagerquist <i>et al.</i> (2008)[†] Calambokidis <i>et al.</i> (2008), Barlow <i>et al.</i> (2011), Baker <i>et al.</i> (2013)*, Wade <i>et al.</i> (2016)

Unit	Unit Name	DPS	References for confirmed (bold) or assumed (non-bold) DPS presence in a unit
8	Prince William Sound Area	MX WNP	Baker et al (1986), Calambokidis et al. (1997), Lagerquist et al. (2008)[†], SPLASH Calambokidis et al. (2008), Barlow et al. (2011), Baker et al. (2013)*, Wade et al. (2016)
9	Northeastern Gulf of Alaska	MX WNP	Lagerquist et al. (2008)[†] Barlow et al. (2011), Calambokidis et al. (2008), Wade et al. (2016)
10	Southeastern Gulf of Alaska	MX	Baker et al. (1985, 1986), Lagerquist et al. (2008)[†], SPLASH, Glacier Bay National Park and J. Straley Investigations Barlow et al. (2011), Calambokidis et al. (2008), Wade et al. (2016)
11	Coastal Washington	MX CAM	SPLASH Barlow et al. (2011), Calambokidis et al. (1997, 2008, 2017), Baker et al. (2013)*, Wade et al. (2016)
12	Columbia River Area	MX CAM	Green et al. (1992) , Barlow et al. (2011), Calambokidis et al. (1997, 2008, 2017), Baker et al. (2013)*, Wade et al. (2016)
13	Coastal Oregon	MX CAM (WNP)^{††}	Mate et al. (2018), Calambokidis et al. (2000)**^{††}, SPLASH, Green et al. (1992) Barlow et al. (2011), Calambokidis et al. (1997, 2008, 2017), Baker et al. (2013)*, Wade et al. (2016)
14	Southern Oregon/ Northern California	MX CAM	SPLASH Barlow et al. (2011), Calambokidis et al. (1997, 2008, 2017), Baker et al. (2013)*, Wade et al. (2016)
15	California North Coast Area	MX CAM	Mate et al. (2018), Green et al. (1992) Barlow et al. (2011), Calambokidis et al. (1997, 2008, 2017), Baker et al. (2013)*, Wade et al. (2016)
16	San Francisco and Monterey Bay Area	MX CAM	Baker et al. 1986 (MX), Calambokidis et al. (2000)**^{††}, SPLASH Barlow et al. (2011), Calambokidis et al. (1997, 2008, 2017), Baker et al. (2013)*, Wade et al. (2016)
17	California Central Coast Area	MX CAM	Steiger et al. 1991 (CAM), Calambokidis et al. (2000)**^{††}, SPLASH Barlow et al. (2011), Calambokidis et al. (1997, 2008, 2017), Baker et al. (2013)*, Wade et al. (2016)

Unit	Unit Name	DPS	References for confirmed (bold) or assumed (non-bold) DPS presence in a unit
18	Channel Islands Area	MX CAM	SPLASH Barlow <i>et al.</i> (2011), Calambokidis <i>et al.</i> (1997, 2008, 2017), Baker <i>et al.</i> (2013)*, Wade <i>et al.</i> (2016)
19	California South Coast Area	MX CAM	Barlow <i>et al.</i> (2011), Calambokidis <i>et al.</i> (1997, 2008, 2017), Baker <i>et al.</i> (2013)*, Wade <i>et al.</i> (2016)

* For Baker *et al.* (2013) information for this table came from supplementary material, Table S1. The supplementary table provided genotype matches for individual whales within a region and between regions (“recaptures”).

** For Calambokidis *et al.* (2000), only used whales listed in Table 3 that specified where in California the whales were seen and also which breeding area and illustrated transit time between feeding and breeding areas. This table did not represent all whales seen in both feeding and breeding areas but otherwise feeding area was not given at fine enough detail.

† Confirmed based on one satellite tagged calf (Lagerquist *et al.* 2008) - a calf tagged off Socorro Island (Mexico) travelled with its mother to areas 7-10.

** One whale was tagged off of Newport, OR by Mate *et al.* (2018) that was assigned to the Western North Pacific DPS using the highest relative likelihood based on genetic analysis, with a 75% likelihood of being from the WNP DPS, and 17.8% from MX DPS. The tag provided no locations, so it is unknown where this whale traveled. It is therefore difficult to determine the use of this area by the tagged whale and there is uncertainty around the DPS assignment.