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Evaluation of Hawai‘i Distinct Population Segment of Humpback Whales as Units Under the Marine Mammal Protection Act

P. R. Wade, E. M. Oleson, and N. C. Young

December 2021

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National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

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Evaluation of Hawai‘i Distinct Population Segment of Humpback Whales as Units Under the Marine Mammal Protection Act

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EXECUTIVE SUMMARY

The Guidelines for Preparing Stock Assessment Reports Pursuant to the 1994 Amendments to the Marine Mammal Protection Act (MMPA) specify that a stock under the MMPA should identify a demographically independent population (DIP). Considerable new data suggest fresh examination of population structure and the potential delineation of Demographically Independent Populations (DIPs) within the subspecies North Pacific humpback whales (*Megaptera novaeangliae kuzira*). The delineation of DIPs is an essential part of the designation of marine mammal stocks under the MMPA. Pursuant to the Endangered Species Act (ESA), the National Marine Fisheries Service (NMFS) conducted a worldwide status review of humpback whales (Bettridge et al. 2015), which identified 14 distinct population segments (DPSs) under the ESA (81 FR 62260, 8 September 2016). One of the DPSs, the Hawaiʻi DPS, consists of humpback whales that winter in Hawaiʻi and feed primarily in the Bering Sea, Gulf of Alaska, Southeast Alaska, and northern British Columbia. Due to its large population size and increasing trend (Bettridge et al. 2015), the Hawaiʻi DPS was considered to not be at high risk of extinction, and therefore did not warrant listing as a threatened or an endangered species under the ESA.

The Hawaiʻi DPS of humpback whales is somewhat aligned with the current Central North Pacific stock under the MMPA, but because the alignment is not complete, the MMPA stock needs to be revised. Both include all humpback whales that winter in Hawaiʻi, and all humpback whales from Hawaiʻi that migrate to feeding areas in Alaska. However, the current Central North Pacific stock includes all humpback whales in Alaska except for whales from the

Western North Pacific (Asia) stock. Therefore, it includes animals originating from the Mexico DPS that migrate to summer feeding grounds in Alaska. It is inappropriate to have whales from multiple DPSs in a single MMPA stock, so it is necessary to revise the definition of the MMPA stock so that it includes humpback whales only from the Hawaiʻi DPS. In addition, given the recent designation of the DPSs, it is worth reviewing whether there might be multiple DIPs within the Hawaiʻi DPS. Following the recommendations of The DIP Delineation Handbook (Martien et al. 2019), we summarize data relevant to demographic independence, primarily movement data from photographic identification and satellite tagging studies, and genetic data.

Whales from Southeast Alaska (SEA) and northern British Columbia (NBC) have a strong migratory connection to Hawaiʻi . During the SPLASH study in 2004-2006, 89% of whales from SEA/NBC that were matched to a wintering ground were matched to Hawaiʻi (Barlow et al. 2011). After correcting the SPLASH data for differences in capture probability, Wade (2021) estimated 98% of whales from SEA/NBC migrate to Hawaiʻi (Wade 2021). The whales that feed in SEA and NBC and winter in Hawaiʻi can be thought of as a Hawaiʻi -SEA/NBC migratory unit, meaning a group of whales that share the same summer and winter migratory destinations. SEA and NBC were significantly different in mitochondrial DNA (mtDNA) ($p < 0.001$) from all other summer areas except each other (Baker et al. 2013). There was also substantial interchange seen between those two areas from photographic identifications, and both areas have nearly identical winter migratory destinations, which are primarily Hawaiʻi with a small percentage of whales going to Mexico, but none to other winter locations. These lines of evidence suggest that SEA and NBC are essentially a single unit, with a very strong migratory connection to

Hawaiʻi . Additionally, genetic samples from SEA and NBC have significant differences in mtDNA F_{ST} from genetic samples from Hawaiʻi , even though Hawaiʻi is their winter migratory destination. This suggests that the Hawaiʻi -SEA/NBC migratory unit is genetically distinct from whales in Hawaiʻi that migrate to other areas in summer. Therefore, both genetic and movement data suggest the Hawaiʻi -SEA/NBC migratory unit meets the criteria to be considered a DIP.

Humpback whales also migrate from Hawaiʻi to the Gulf of Alaska, Aleutian Islands, Bering Sea, and Russia. This is referred to here as the Hawaiʻi -Northern Pacific unit (Hawaiʻi -NorPac for short). Currently available movement data are consistent with the possible existence of multiple DIPs within the Hawaiʻi -NorPac unit. Although there may be sufficient data to delineate further DIPs within the Hawaiʻi -NorPac unit, the photographic data have not been fully stratified in the way required to evaluate additional putative DIPs. Thus, for the Hawaiʻi DPS, there are data to delineate one DIP (Hawaiʻi -SEA/NBC) but insufficient analyses (and perhaps data) to delineate DIPs within the remaining whales in the Hawaiʻi -NorPac unit. Additionally, it is not clear in what unit to place the small number of whales that migrate between Hawaiʻi and southern British Columbia/Washington. Additional studies may provide clarification, but some available genetic results are confounded by the fact that in these other areas there is a larger mixture of whales from multiple winter/breeding DPS areas (Asia, Hawaiʻi , and Mexico).

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INTRODUCTION

Many humpback whales occupy relatively coastal habitats for most of the year, which makes obtaining both biopsies and photographic identification of their flukes possible. Between 2004 and 2006, a basin-wide study took place on nearly all North Pacific summer and winter areas (Calambokidis et al. 2008, Barlow et al. 2011, Baker et al. 2013). The study, known as SPLASH (Structure, Population Levels, And Status of Humpbacks), produced substantial photographic and genetic data regarding the population structure of North Pacific humpback whales. The design of the study obtained data in summer feeding areas and wintering areas within the North Pacific that were known at the time of the study. Following the SPLASH study, the National Marine Fisheries Service (NMFS) conducted a worldwide status review of humpback whales (Bettridge et al. 2015), which supported the identification of 14 DPSs under the ESA (81 Federal Register 62260; 8 September 2016). One of the DPSs that was identified is the Hawaiʻi DPS, representing the group of humpback whales that winter in Hawaiʻi .

It is well known that a large number of humpback whales use the waters surrounding the Hawaiian Islands each winter (Calambokidis et al. 1997). While peak densities are consistently found in the four Island region and Penguin Bank, aerial surveys have shown increasing densities off Hawaiʻi Island and in the Kauai and Niihau region (Mobley et al. 1999, 2001). Abundance for the main Hawaiian Islands was estimated to be ~10,000 whales during the SPLASH project (Wade 2021). Several studies confirm extensive movement of individuals between the islands (Cerchio 1998, Calambokidis et al. 2008). During development of the status review (Bettridge et al. 2015), the Hawaiʻi population was determined to be a discrete unit based on re-sight data as well as findings of significant genetic differentiation between it and other breeding areas in the North Pacific. The humpback wintering area in Hawaiʻi is separated by the greatest geographic distance from neighboring populations and was significantly different from other winter areas in both frequencies of mitochondrial DNA (mtDNA) haplotypes and nuclear DNA (nDNA) (microsatellite) alleles (Baker et al. 2008). Subsequently, the Hawaiʻi population was identified as a DPS but did not warrant listing as a threatened or an endangered species under the ESA (81 Federal Register 62260, 8 September 2016). The winter distribution of the Hawaiʻi DPS is in the Hawaiian Archipelago. Humpback whales from the Hawaiʻi DPS feed across a broad geographic range from Washington to Russia, with concentrations in Southeast Alaska, the northern and western Gulf of Alaska, and Bering Sea feeding grounds.

NMFS' Guidelines for Preparing Stock Assessment Reports Pursuant to the 1994 Amendments to the MMPA defines the term 'demographic independence' to mean that

> …the population dynamics of the affected group is more a consequence of births and deaths within the group (internal dynamics) rather than immigration or emigration (external dynamics). Thus, the exchange of individuals between population stocks is not great enough to prevent the depletion of one of the populations as a result of increased mortality or lower birth rates (NMFS 2016).

The NMFS policy on stock designation (NMFS 2019) indicates that stocks should generally be composed of a single demographically independent population (DIP), though notes that in some situations it may be impractical to manage DIPs as stocks. One such exception is when DPSs are designated under the ESA, though the policy notes that even within that case, separate DIPs within the DPS may warrant recognition as stocks under the MMPA.

The Hawaiʻi DPS of humpback whales is somewhat aligned with the current Central North Pacific stock under the MMPA, but because the alignment is not complete, the MMPA stock needs to be revised. Both include all humpback whales that winter in Hawaiʻi , and all humpback whales from Hawaiʻi that migrate to feeding areas in Alaska. However, the current Central North Pacific stock includes all humpback whales in Alaska except for whales from the Western North Pacific (Asia) stock. Therefore, it includes animals originating from the Mexico DPS that migrate to summer feeding grounds in Alaska. Having whales from multiple DPSs in a single MMPA stock is incompatible with the stock policy, so it is necessary to revise the definition of the MMPA stock so that it includes humpback whales only from the Hawaiʻi DPS. In addition, given the DPS has only recently been identified, it is worth reviewing whether there might be multiple DIPs within the Hawaiʻi DPS. Following the recommendations of The DIP Delineation Handbook (Martien et al. 2019), we summarize data relevant to demographic independence, primarily movement data from photographic identification and satellite tagging studies, and genetic data. The evaluation of Central America, Mexico, and Western North Pacific DPS whales under the MMPA are addressed in separate NOAA Technical Memoranda (Taylor et al. in review, Martien et al. in review, Oleson et al. in review).

The DIP Delineation Handbook reviewed lines of evidence (LoEs) according to strength in delineating DIPs. Three LoEs were considered as ‘strong’ for all or nearly all marine mammal species when robust data demonstrating differences between groups were available, including genetics, morphology, and movement data. We summarize the data available on genetics and movements for the Hawaiʻi humpback whale DPS below. No data allowing meaningful morphological comparisons are available within the North Pacific humpback whale subspecies.

Martien et al. (2020) suggest that humpback research and management should focus on groups of animals that share the same feeding ground and wintering ground, which can be referred to as a 'migratory whale herd' or 'migratory whale group'. Recruitment into a migratory group is almost entirely through maternally-directed learning of the migratory destinations. Available photographic and genetic data show strong fidelity of animals to a given feeding and wintering ground, and therefore to a migratory group, suggesting very little dispersal (permanent movement of animals) between migratory groups. If dispersal between migratory groups, such as between summer feeding areas, is low enough to render them demographically independent, a migratory whale group is a special case of a DIP.

Migratory whale groups may interbreed with other groups to varying extents, and therefore may not be reproductively isolated. However, interbreeding among groups only results in the exchange of genetic material between them, not an exchange of animals. It therefore has no impact on the demography of either group. Because gene flow (the transfer of genetic material between groups through interbreeding) can occur without dispersal (the transfer of individuals between groups), reproductive isolation is not required between stocks under the MMPA (Martien et al. 2019).

LINES OF EVIDENCE FOR DEMOGRAPHIC INDEPENDENCE

Movements

Strong fidelity to both feeding and wintering areas has been observed in North Pacific humpback whales, but movements between feeding and wintering areas are often complex and varied (Calambokidis et al. 2008, Barlow et al. 2011). An overall pattern of migration has recently emerged. Asia and Mexico/Central America are the dominant wintering areas for humpback whales that migrate to feeding areas in lower latitudes and more coastal areas on each side of the Pacific Ocean, such as California and Russia. The Revillagigedo Archipelago and Hawaiian Islands are the primary winter migratory destinations for humpback whales that feed in the more central and higher latitude areas (Calambokidis et al. 2008). However, there are exceptions to this pattern and it seems that complex population structure and strong site fidelity coexist with lesser known, but potentially high, levels of plasticity in the movements of humpback whales (Salden et al. 1999).

In the SPLASH study, sampling in Hawaiʻi occurred on Kauai, Oahu, Penguin Bank (off the southwest tip of the island of Molokai), Maui, and Hawaiʻi Island. Interchange within Hawaiʻi was extensive (Table 1). Although most of the Hawaiʻi identifications came from the Maui sub-area, identifications from the Hawaiʻi Island and Kauai at the eastern and western end of the region showed a high rate of interchange with Maui. Satellite tagging of humpback whales in Maui in 2015 and 2018 showed substantial movements of whales between the main Hawaiian Islands (MHI) (Palacios et al. 2019), including movement to Kauai and Niihau at the western end of the MHI, and movement to Hawaiʻi Island at the eastern end of the MHI. In summary, there does not appear to be any evidence of separation between the main Hawaiian Islands.

Subsequent to the SPLASH project, a survey in 2007 documented humpback whales from a number of locations in the Northwestern Hawaiian Islands (NWHI) at relatively low densities (Johnston et al. 2007). Humpback whales were seen and/or heard across nearly the entire extent of the NWHI, from Nihoa in the east to Lisianski Island in the west. They also estimated that the amount of shallow, warm-water habitat in the NWHI was almost double that available in the main Hawaiian Islands. A Pacific Islands Fisheries Science Center (PIFSC) survey in April 2019 further explored the distribution of humpback whales in the NWHI, encountering at least 150 animals between Middle Bank and the Brooks Banks and collecting approximately 50 photographic identifications (photo-IDs). The NWHI photo-ID catalog has been incorporated into Happywhale.com (Cheeseman et al. 2017), which provides an automated matching algorithm across all images submitted, and this has resulted in several matches to the MHI (K. Yano, NMFS PIFSC, pers. comm). Given these linkages and the proximity of the NWHI to the main Hawaiian Islands, it is presumed that humpback whales in the NWHI are part of the Hawaiʻi DPS.

It has long been known that many humpback whales from Hawaiʻi move to summer feeding areas in Alaska (Calambokidis et al. 2008). Photographic ID matches from the SPLASH project show that areas in Alaska and northern British Columbia appear to be the primary migratory destination for whales from Hawaiʻi (Table 2). However, there are matches from Hawaiʻi to every summer feeding area that was sampled, except for California/Oregon.

During the SPLASH study in 2004-2006, 89% of whales from SEA/NBC that were matched to a wintering ground were matched to Hawaiʻi (Barlow et al. 2011). Matching rates from data collected in recent years are comparable to those from SPLASH (Ted Cheeseman, happywhale.com, pers. comm.) However, the raw photographic matching rates do not account for differences in capture probabilities between strata. To account for this, Wade (2021) used the SPLASH data and methods fully summarized in Wade et al. (2016) to estimate the probability that whales moved between broadly defined summer and winter areas (Figure 1). He found that for Southeast Alaska/northern British Columbia, an estimated 98% of the whales had a migratory destination of Hawaiʻi , with the remaining whales migrating to Mexico.

The other summer feeding areas in Alaska also have a high percentage of whales that are estimated to migrate to Hawaiʻi (Wade 2021). In the Aleutian Islands/Bering Sea and Gulf of Alaska, 7% and 11% of the whales, respectively, had a migratory destination of Mexico, with a small percentage of whales, 2% and 0.3%, having a migratory destination of Asia. Therefore, most areas in Alaska contain a mixture of whales from two or three different winter/breeding areas that have been determined to be DPSs (Asia, Hawaiʻi , and Mexico). No whales from the Alaska feeding areas are estimated to migrate to Central America. For the Russia feeding areas, most of the whales (91%) are estimated to migrate to Asia, with most of the remaining whales (9%) estimated to migrate to Hawaiʻi .

For winter-to-summer migration, an estimated 98% of the whales in Hawaiʻi had a migratory destination to one of the three feeding areas in Alaska and northern British Columbia, with the majority going to Southeast Alaska/northern British Columbia. The remaining small percentage of whales are estimated to migrate to Russia (0.3%) or southern British Columbia/Washington (1.1%). Although they represent a small percentage of the whales in Hawaiʻi , because the abundance in southern British Columbia/Washington was relatively low (~350 whales in 2005), this still represented a majority of the whales in southern British Columbia/Washington. An estimated 69% of the whales in southern British Columbia/Washington migrate to Hawaiʻi , with the rest migrating to Mexico and Central America (Wade 2021).

Note that in the Wade et al. (2016) study, the Aleutian Islands/Bering Sea stratum included northern areas in Russia (Gulf of Anadyr, Chukotka Peninsula) and Kamchatka was its own stratum, whereas now in Wade (2021) all the Russia sub-regions are combined into the Russia stratum. Following SPLASH, a long-term study of humpback whales in Russian waters was initiated. Titova et al. (2019) used photographs of 1,929 whales from nine regions within the Russian Far East between 2004 and 2017 to assess within feeding area associations as well as linkages between specific feeding areas within Russia and winter areas. Most photographic matches were to winter areas in Asia, consistent with what was estimated in Wade (2021), but matches were made from several locations in Russia to Hawaiʻi , including the Commander Islands, the Gulf of Anadyr and Chukotka Peninsula, and the southern Kamchatka Peninsula (Figure 2).

Movements between summer feeding areas were also documented in the SPLASH study, though, due to the strong maternal fidelity to feeding areas, at a fairly low rate. One exception was Southeast Alaska and northern British Columbia, where, for example, of all the whales identified in northern British Columbia in 2014 that were also identified in 2015, 14% (13 of 92) of them were identified in Southeast Alaska (Table 3). Tagging data in Palacios et al. (2019) also show several whales moving from Hawaiʻi to northern British Columbia, then continuing on to Southeast Alaska.

Other movements between summer feeding areas occur both within and between years. Interestingly, within 2004, 10 whales matched between the northern Gulf of Alaska (730 unique IDs) and Southeast Alaska (808 unique IDs); in contrast, only five whales matched between those two feeding areas between the years 2004 and 2005 (Calambokidis et al. 2008).

One possible explanation for that result was that, because of limited ship time in 2005, there was much more effort in offshore waters in the Gulf of Alaska in 2004 than in 2005. A number of the matches seen in 2004 were from offshore waters in the Gulf of Alaska to Southeast Alaska, so it is possible these were whales with a migratory destination of Southeast Alaska, but whose migration route took them first through the offshore waters of the Gulf of Alaska. Although such a migration route did not occur in satellite tracked whales in Palacios et al. (2019), two whales from Hawaiʻi did migrate relatively due north to the eastern Aleutians, and then moved >1,500 km due west to an area south of the Commander Islands, rather than migrating straight from Hawaiʻi to that location. This might represent a migration strategy for some whales. Somewhat similarly, many of the whales tracked from Hawaiʻi to Southeast Alaska first intersected the coast along the islands of Haida Gwaii in British Columbia, and then moved north along the coast into Southeast Alaska (Figures 3 & 14 in Palacios et al. 2019). Other inter-year matches between summer areas in SPLASH included 7 matches between the northern Gulf of Alaska (primarily Kodiak, lower Cook Inlet, Kenai, and Prince William Sounds) and the western Gulf of Alaska (primarily the Shumagin Islands and the Alaska Peninsula).

Genetics

Samples collected during SPLASH provided a large dataset for making genetic comparisons within North Pacific humpback whales (Baker et al. 2013). In comparisons between winter areas, Hawaiʻi was found to be significantly different from all other winter areas, including the Philippines (F_{ST} = 0.276, $p < 0.001$), Okinawa (F_{ST} = 0.268, $p < 0.001$), Ogasawara (F_{ST} = 0.130, $p < 0.001$), Mexico-Revillagigedo (F_{ST} = 0.075, $p < 0.001$), Mexico-Baja

(F_{ST} = 0.075, p < 0.001), Mexico-mainland (F_{ST} = 0.081, p < 0.001), and Central America (F_{ST} = 0.228, p < 0.001). More recently, Hill et al. (2020), using 24 samples from the Mariana Archipelago, examined mtDNA haplotype frequencies compared to the SPLASH dataset (Baker et al. 2013). They found significant differences between Mariana whales and those from four breeding grounds, including Hawaiʻi .

Baker et al. (2013) compared winter to summer areas as well, which resulted in some interesting but somewhat complex results. They found a significant difference in mtDNA between Hawaiʻi and Southeast Alaska (F_{ST} = 0.072, p < 0.001) and northern British Columbia (F_{ST} = 0.034, p < 0.001), as well as a difference in nDNA. Because an estimated 98% of the whales in Southeast Alaska/northern British Columbia (SEA/NBC) migrate to Hawaiʻi (Wade 2021), the apparent conclusion to draw from this is that the migratory group that moves from Hawaiʻi to SEA/NBC has significant genetic differences from the rest of the whales that winter in Hawaiʻi and migrate to different summer feeding areas. Hawaiʻi was also significantly different from most of the other summer feeding areas, but, because these areas have larger proportions of whales from other winter areas (e.g., Mexico), the same conclusion cannot be drawn; for example, Hawaiʻi might be significantly different from the Bering Sea because the Bering Sea contains a mix of whales from Hawaiʻi , Mexico, and Asia. Interestingly, Hawaiʻi was not significantly different from the northern Gulf of Alaska (primarily Kodiak Island and Prince William Sound) in either mtDNA or microsatellite DNA, despite large sample sizes (Baker et al. 2013).

Baker et al. (2013) also compared summer feeding areas to each other. Southeast Alaska was significantly different in mtDNA from all other summer feeding areas except northern British Columbia, with F_{ST} values ranging from 0.191 to 0.343. The same was true for northern British Columbia; it was significantly different from all other summer feeding areas except Southeast Alaska. Comparisons between other areas in Alaska are not as clear. The Bering Sea (BS) was not significantly different from the eastern Aleutian Islands (EAL) (F_{ST} = 0.000), and the EAL were not significantly different from the western Gulf of Alaska (WGOA, F_{ST} = 0.003) or from the northern Gulf of Alaska (NGOA, F_{ST} = 0.011). However, the BS was significantly different from the WGOA (F_{ST} = 0.023, $p < 0.001$) and from the NGOA (F_{ST} = 0.039, $p < 0.001$). It can be seen that in all the pairwise comparisons between those other four sampling areas in Alaska (BS, EAL, WGOA, NGOA), even when statistically significant, the F_{ST} value is lower (0.023 to 0.039) than in comparisons of those areas to SEA (0.095 to 0.245), suggesting those areas are not as strongly differentiated from each other as SEA is from other areas. On the other hand, the higher F_{ST} in comparisons to SEA may be simply due to the lower haplotypic diversity found there. Finally, it needs to be remembered that these comparisons between summer feeding areas are somewhat confounded by the mixture of whales from different winter/breeding areas (Asia and Mexico), which are estimated to represent 9% of the whales in the Aleutian Islands and Bering Sea, and 11% of the whales in the Gulf of Alaska (Wade 2021).

The southern British Columbia/Washington (SBC/WA) feeding area was significantly different from every other summer area (except the western Aleutians, which had a very small sample size) and every winter area (Baker et al. 2013). Again, interpretation of this is somewhat complex. Significant differences between California/Oregon (CA/OR) and SBC/WA may be explained by the fact that SBC/WA whales are a mix of whales from Hawaiʻi and Mexico, whereas CA/OR whales are a mix of whales from Mexico and Central America. Similarly, the significant difference between SBC/WA and Hawaiʻi , even though the majority of whales from SBC/WA migrate to Hawaiʻi , might be explained by the fact that approximately one third of the whales in SBC/WA are from Mexico. The F_{ST} values are larger in the comparisons of SBC/WA to other summer feeding areas as compared to comparisons to Hawaiʻi and Mexico. For example, the F_{ST} between SBC/WA and Southeast Alaska was 0.191, and to CA/OR was 0.107, whereas the F_{ST} between SBC/WA and winter areas was 0.057 for Hawaiʻi and 0.026 for mainland Mexico.

A recent genetic mixed-stock apportionment study has also estimated the proportion of humpback whales on feeding grounds that are from each of the four winter areas (Lizewski et al. 2021); this provides alternative movement estimates using a data set other than the photo-identification data. One notable result from that study was the estimate that a very high proportion of the whales in SEA/NBC were from Hawaiʻi (Lizewski et al. 2021), with the estimate being very similar to the estimated 98% estimated from the photo-identification data.

CONCLUSIONS

Martien et al. (2019) identify three Lines of Evidence (LoE) considered to be 'strong' – movements, genetics, and morphology. Robust data from a single strong LoE are sufficient to meet the DIP definition, where 'robust data' means that there has been appropriate evaluation of all relevant factors (e.g., age and sex difference, sample size, analytical methods, etc.) such that the observed difference is real, not a sampling or analytical artifact. Based on the review of information above, we conclude that the Hawaiʻi -SEA/NBC migratory group is a DIP. We suggest that the rest of the Hawaiʻi DPS be placed into a second management unit, the Hawaiʻi -NorPac unit.

Hawaiʻi -SEA/NBC DIP

Data from two strong LoEs (movements and genetics) suggest that the Hawaiʻi -SEA/NBC group of whales (the whales that migrate between those locations) meet the definition of a DIP. As discussed above, SEA and NBC were significantly different in mtDNA ($p < 0.001$) from all other summer feeding areas except each other. There was also substantial interchange seen between those two areas from photographic identifications, and both areas have nearly identical winter migratory destinations, which are primarily Hawaiʻi (98%) with a small percentage migrating to Mexico, but none to other winter locations. Northern British Columbia may be a recent expansion of what was the Southeast Alaska population. These lines of evidence suggest that Southeast Alaska and northern British Columbia are nearly a single feeding aggregation with a very strong migratory connection to Hawaiʻi . The fact that SEA and NBC are significantly different genetically from samples from Hawaiʻi , even though Hawaiʻi is the winter migratory destination for 98% of the whales that use those feeding areas, suggests whales that migrate from SEA/NBC to Hawaiʻi are genetically distinct from the other whales in Hawaiʻi that migrate to other feeding areas in summer. This indicates the Hawaiʻi -SEA/NBC group is a DIP.

Geographic Range

Recent passive acoustic observations from the central and western Pacific indicate humpback whales are heard in open-ocean regions away from known migratory pathways during the breeding season (Klinck et al. 2015, Darling et al. 2019, 2021, Allen et al. 2021). While these observations do not suggest discovery of a large aggregation, they do provide evidence that humpback whale winter areas may be more dispersed than traditionally thought, and such dispersed winter areas may represent a substantial portion of the whales in Alaska feeding areas. This may suggest that the concept of a 'Hawaiʻi ' DPS, and DIPs within it, may need to be defined to represent a broader winter area than just the areas immediately surrounding Hawaiʻi itself. For example, Allen et al. (2021) report humpback song at Kingman Reef (near Palmyra Atoll) and Wake Atoll, and it is possible (if not likely) that whales there would be part of the Hawaiʻi DPS, as well. Therefore, the winter range of this DIP includes all of the Hawaiian Archipelago, and may also include oceanographic habitat to both the west and the east.

The summer range of this DIP is Southeast Alaska and northern British Columbia, including offshore waters. The division used for the SPLASH data between northern and southern British Columbia is approximately at the mid-point of Vancouver Island (Calambokidis et al. 2008, Fig. 2). There is some uncertainty of whether the relatively small number of humpback whales in southern British Columbia and Washington that migrate to Hawaiʻi should also be included in this DIP (see discussion below).

Potential Abundance Estimation

An abundance estimate for the Hawaiʻi – SEA/NBC DIP can be obtained by estimating the total abundance of SEA/NBC and prorating based on the proportion of animals that migrate to Hawaiʻi rather than Mexico. From the SPLASH photo-identification data, abundance for the SEA/NBC region for 2004-2005 was estimated at 3,005 (CV=0.042) by a simple Lincoln-Peterson estimator, and as 5,890 (CV=0.075) from a multi-strata estimator (Wade 2021). Photo-identification data have continued to be collected in the region, so it is potentially possible to estimate abundance using more current data, subject to a review of whether there has been sufficient geographic coverage of the region. Abundance can be prorated based on the movement probabilities estimated by Wade (2021) and updated based on newer photographic and genetic assignment data as they become available.

A potential alternative method for estimating abundance would be to estimate the abundance of humpback whales in Hawaiʻi , and then use migratory destination estimates and/or genetic mixed stock analyses to prorate what proportion of the whales in Hawaiʻi will migrate to Southeast Alaska and northern British Columbia. A 2020 line-transect survey in the main Hawaiian Islands during the winter months may provide a basis for such an estimate once density analyses are complete.

Hawaiʻi -NorPac Unit

Movement data also show a strong migratory connection between Hawaiʻi and the other regions within Alaska, with relatively little interchange of individuals between areas, suggesting there may be multiple DIPs within the rest of Alaska. However, the currently available genetic data are not particularly useful because of the mixture of whales from the Mexico and Western North Pacific DPSs in the Alaska summer areas. Given that, for now, the group of whales that migrate between Russia, western Alaska (Bering Sea and Aleutian Islands), and central Alaska (Gulf of Alaska excluding Southeast Alaska), and Hawaiʻi can be referred to as the Hawaiʻi -Northern Pacific (NorPac) unit, with the understanding that it includes all humpback whales in Russia, the Bering Sea, the Aleutian Islands, and the Gulf of Alaska (excluding Southeast Alaska) that migrate to Hawaiʻi . The Hawaiʻi -NorPac unit may be a DIP or, as mentioned above, a collection of DIPs that cannot be distinguished yet because the appropriate analyses and perhaps data are not yet available. Currently, there is no way to assign individual whales in Hawaiʻi to either DIP or unit, unless that whale has been identified from a summer feeding area. However, the probability a whale is from one unit or another can be estimated from the migration probabilities in Wade (2021).

Note that whales in Russia and Alaska that migrate to Mexico, including those that migrate from SEA/NBC to Mexico, are considered part of the Mexico-North Pacific unit (Martien et al. in review). Similarly, whales in Russia and Alaska that migrate to Asia are considered part of the Philippines/Okinawa-Northern Pacific group or the Mariana Islands-Northern Pacific group (Oleson et al. in review).

It is possible that further studies could help clarify whether there are units that represent further DIPs within the Hawaiʻi -NorPac unit. For example, genetic samples from whales identified in both Hawaiʻi and their summer destination (e.g., Bering Sea) could be compared to genetic samples from whales identified in both Hawaiʻi and other locations in

Alaska (e.g., Gulf of Alaska). If that type of comparison showed a significant difference in mtDNA, that would then suggest the possibility these units also represent DIPs.

Further clarification is also hindered by the lack of current studies in large portions of the western half of the northern North Pacific. Aside from recent efforts in Russian waters, there has not been substantial additional effort in the western Aleutians, Bering Sea, or western Gulf of Alaska since SPLASH, hindering more detailed examination of the extent of use of this region by whales from Hawaiʻi .

One interesting result is that the northern Gulf of Alaska is not significantly different in mtDNA from Hawaiʻi , whereas the western Gulf of Alaska, Aleutian Islands, and Bering Sea are significantly different from Hawaiʻi . Additionally, although the number of whales moving between the areas are not large, there is interchange between Southeast Alaska and the northern Gulf of Alaska, and between the northern Gulf of Alaska and the western Gulf of Alaska. One possible hypothesis to explain the lack of significance in mtDNA between the northern Gulf of Alaska and Hawaiʻi is that perhaps that area represents a mixture of different migratory groups to the east (SEA/NBC) and west (WGOA, Aleutians, Bering), and so approximates the mixture of the migratory groups that are in Hawaiʻi in winter.

It is not clear what the observed migration between Hawaiʻi and southern British Columbia/Washington represents, such as whether this represents a distinct migratory group of whales (e.g., a Hawaiʻi -SBC/WA migratory group). Genetically, there are fairly strong differences between SBC/WA and other summer areas. Despite that, it is conceivable that these whales could be part of the SEA/NBC-Hawaiʻi migratory group, with the genetic difference between the areas due to the mixture of whales from Mexico; in fact, there are a small number of matches (5) between SBC/WA and NBC (Table 3). An alternative explanation is that the Hawaiʻi -origin animals represent a Hawaiʻi -SBC/WA migratory group. Based on the information and analyses available at this time, we cannot determine which alternative applies. They cannot be a part of the population units in CA/OR, given that those whales have different migratory destinations and are part of different DPSs (Mexico and Central America). A considerable number of photographic and genetic samples have been collected from the waters off of WA, SEA, and all of British Columbia in the nearly two decades since the SPLASH study. Analysis of these data may help to clarify the status and affiliation of the SBC/WA animals.

Geographic Range

The winter range of this unit is identical to the Hawaiʻi -SEA/NBC DIP, and includes all of the Hawaiian Archipelago, and may also include oceanographic habitat to both the west and the east of Hawaiʻi . Currently, there is no way that individual whales in Hawaiʻi could be assigned to either DIP or unit, unless that whale has been identified from a summer feeding area. However, the probability a whale is from one unit or another can be estimated from the migration probabilities in Wade (2021). Also, genetic assignment methods could provide a likelihood of population origins of individuals, depending on the true differences of source populations and the power of the genetic markers.

The summer range of this unit includes eastern Russia (Kamchatka, Gulf of Anadyr, and Commander Islands), the Aleutian Islands and Bering Sea, and the Gulf of Alaska, including offshore waters. The summer range specifically excludes Southeast Alaska and northern British

Columbia. At this point in time, whales found in summer in in southern British Columbia and northern Washington are also included in this unit; this issue will be revisited if new stock designations are proposed for these regions.

Potential Abundance Estimation

Estimating the abundance of this unit may be more complex than estimating the abundance of the Hawaiʻi -SEA/NBC DIP, as the summer areas in Russia and Alaska contain varying mixtures of whales from Hawaiʻi , but also whales from the WNP and Mexico DPSs. One potential method would be to estimate abundance for Hawaiʻi , then subtract the estimated abundance of the Hawaiʻi -SEA/NBC DIP, to estimate abundance for this unit. For example, using the multi-strata estimates from Wade (2021), abundance for this unit in 2004-2005 would be approximately 5,700.

CITATIONS

Allen, A.N., M. Harvey, L. Harrell, K.P. Merkens, C.C. Wall, A. Jansen, K. Cattiau, and E.M. Oleson. 2021. A convolutional neural network for automated detection of humpback whale song in a diverse long-term acoustic dataset. Front. Mar. Ecol. 8: 607321. doi: 10.3389/fmars.2021.607321.

Baker, C.S., D. Steel, J. Calambokidis, E.A. Falcone, U. Gozález-Peral, J. Barlow, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, D.K. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urbán R., P. R. Wade, D. Weller, B.H. Witteveen, and M. Yamaguchi. 2013. Strong maternal fidelity and natal philopatry shape genetic structure in North Pacific humpback whales. Mar. Ecol. Prog. Ser. 494: 291-306. doi: 10.3354/meps10508.

Barlow, J., J. Calambokidis, E.A. Falcone, C.S. Baker, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R. LeDuc, D.K. Mattila, T.J. Quinn, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urbán R., P. Wade, D. Weller, B.H. Witteveen, and M. Yamaguchi. 2011. Humpback whale abundance in the North Pacific estimated by photographic capture-recapture with bias correction from simulation studies. Mar. Mammal Sci. 27(4): 793-818. doi: 10.1111/j.1748-7692.2010.00444.x.

Bettridge, S., C.S. Baker, J. Barlow, P.J. Clapham, M. Ford, D. Gouveia, D.K. Mattila, R.M. Pace III, P.E. Rosel, G.K. Silber, and P.R. Wade. 2015. Status review of the humpback whale (*Megaptera novaeangliae*) under the Endangered Species Act. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-540. 240 p.

Calambokidis, J., E.A. Falcone, T.J. Quinn, A. Burdin, P. J. Clapham, J. K. N. Ford, C. M. Gabriele, R. LeDuc, D. Mattila, L. Rojas-Bracho, J. M. Straley, B. L. Taylor, J. Urbán R., D. Weller, B. H. Witteveen, M. Yamaguchi, A. Bendlin, D. Camacho, K. Flynn, A. Havron, J. Huggins, and N. Maloney. 2008. SPLASH: Structure of populations, levels of abundance and status of humpback whales in the north Pacific. Cascadia Research. Final report for contract AB133F-03-RP-00078. 57 p.

Calambokidis, J., G. H. Steiger, J. M. Straley, T. Quinn, L. M. Herman, S. Cerchio, D. R. Salden, M. Yamaguchi, F. Sato, J. Urban R., J. Jacobson, O. von Ziegesar, K. C. Balcomb, C. M. Gabriele, M. E. Dahlheim, N. Higashi, S. Uchida, J. K. B. Ford, Y. Miyamura, P. Ladrón de Guevara, S. A. Mizroch, L. Schlender, and K. Rasmussen. 1997. Abundance and population structure of humpback whales in the North Pacific basin. Final Contract Report 50ABNF500113 to Southwest Fisheries Science Center, 8901 La Jolla Shores Drive, La Jolla, CA 92037. 72 p.

Cerchio, S., C. M. Gabriele, T. F. Norris, and L. M. Herman. 1998. Movements of humpback whales between Kauai and Hawaii: implications for population structure and abundance estimation in the Hawaiian Islands. Mar. Ecol. Progr. Ser. 175: 13-22.

Cheeseman, T., T. Johnson, K. Southerland, and N. Muldavin. 2017. Happywhale: Globalizing marine mammal photo identification via a citizen science web platform. Paper SC/67A/PH/02 submitted to the Scientific Committee of the International Whaling Commission, May 2017, Bled, Slovenia.

Darling, J.D, B. Goodwin, A.J. Taufmann, M.G. Taylor. 2021. Humpback whales (Megaptera novaeangliae) detected by autonomous Wave Glider in tropical deep seas between Hawaiʻi and Western Pacific winter assemblies. Mar. Mammal Sci. 37(3): 1101-1108. doi: 10.1111/mms.12771.

Darling, J.D., B. Goodwin, M.K. Goodoni, A.J. Taufmann, and M.G. Taylor. 2019. Humpback whale calls detected in tropical ocean basin between known Mexico and Hawaiʻi breeding assemblies. J. Acoust. Soc. Am. 145: EL534–EL540. doi: 10.1121/1.5111970

Hill, M.C., A.L. Bradford, D. Steel, C.S. Baker, A.D. Ligon, A.C. Ü, J.V. Acebes, O.A. Filatova, S. Hakala, N. Kobayashi, Y. Morimoto, H. Okabe, R. Okamoto, J. Rovers, T. Sato, O.V. Titova, R.K. Uyeyama, and E.M. Oleson. 2020. Found: A missing breeding ground for endangered western North Pacific humpback whales in the Mariana Archipelago. Endang. Species Res. 41: 91-103. doi: 10.3354/esr01010.

Johnston, D. W., M.E. Chapla, L.E. Williams, and D.K. Mattila. 2007. Identification of humpback whale *Megaptera novaeangliae* wintering habitat in the Northwestern Hawaiian Islands using spatial habitat modeling. Endang. Species Res. 3: 249-257. doi: 10.3354/esr00049.

Klinck, H., S.L. Nieukirk, S. Fregosi, K. Klinck, D.K. Mellinger, S. Lastuka, G. B. Shilling, and J. C. Luby. 2015. Cetacean Studies on the Hawaiʻi Range Complex in December 2014 - January 2015: Passive Acoustic Monitoring of Marine Mammals Using Gliders. Final Report under Contract No. N62470-10-D-3011, Task Order KB25, issued to HDR Inc. October 2015. Honolulu, HI: Naval Facilities Engineering Command (NAVFAC) Pacific, Pearl Harbor.

Lizewski, K., D. Steel, K. Lohman, G.R. Albertson, Ú. González Peral, J. Urbán R., J. Calambokidis, C.S. Baker. 2021. Mixed-stock apportionment of humpback whales from feeding grounds to breeding grounds in the North Pacific based on mtDNA. Paper SC/68c/IA01 submitted to the Scientific Committee of the International Whaling Commission.

Martien, K.K., B.L. Hancock-Hanser, M. Lauf, B.L. Taylor, F.I. Archer, J. Urbán Ramirez, D. Steel, C. Scott Baker, and J. Calambokidis. 2020. Progress report on genetic assignment of humpback whales from the California-Oregon feeding aggregation to the Mainland Mexico and Central America wintering grounds. U.S. Dep. Commer., NOAA-TM-NMFS-SWFSC-635.

Martien, K.K., A.R. Lang, B.L. Taylor, S.E. Simmons, E.M. Oleson, P.L. Boveng, and M.B. Hanson. 2019. The DIP delineation handbook: a guide to using multiple lines of evidence to delineate demographically independent populations of marine mammals. U.S. Dep. Commer., NOAA-TM-NMFS-SWFSC-622, 133 p.

Martien, K.M., B.L. Taylor, F. Archer, K. Audley, J. Calambokidis, T. Cheeseman, J. De Weerdt, A. Frisch Jordán, P. Martínez- Loustalot, C.D. Ortega-Ortiz, E.M. Patterson, N. Ransome, P. Ruvelas, and J. Urbán R. In review. Evaluation of Mexican Distinct Population Segment of Humpback Whales as units under the Marine Mammal Protection Act. U.S. Dep. Commer., NOAA-TM-NMFS-SWFSC-xxxxx, xx p.

Mobley, J., Jr., S. Spitz, R. Grotefendt, P. Forestell, A. Frankel, and G. Bauer. 2001. Abundance of humpback whales in Hawaiian waters: Results of 1993-2000 aerial surveys. Report to the Hawaiian Islands Humpback Whale National Marine Sanctuary. 16 p.

Mobley, J. R., Jr., G. B. Bauer, L. M. Herman. 1999. Changes over a ten-year interval in the distribution and relative abundance of humpback whales (Megaptera novaeangliae) wintering in Hawaiian waters. Aquat. Mamm. 25(2): 63-72.

NMFS. 2019. Reviewing and designating stocks and issuing Stock Assessment Reports under the Marine Mammal Protection Act. National Marine Fisheries Service Procedure 02-204-03. Available at: https://media.fisheries.noaa.gov/dam-migration/02-204-03.pdf.

NMFS. 2016. Guidelines for preparing stock assessment reports pursuant to the 1994 amendments to the MMPA. National Marine Fisheries Service Instruction 02-204-01. Available at: https://www.fisheries.noaa.gov/national/marine-mammal-protection/guidelines-assessing-marine-mammal-stocks.

Oleson, E. M., P. R. Wade, and N. C. Young. In review. Evaluation of the Western North Pacific Distinct Population Segment of Humpback Whales as units under the Marine Mammal Protection Act. U.S. Dep. Commer., NOAA-TM-NMFS-PIFSC-xxxxx, xx p.

Palacios, D.M., B.R. Mate, C.S. Baker, C.E. Hayslip, T.M. Follett, D. Steel, B.A. Lagerquist, L.M. Irvine, and M.H. Winsor. 2019. Tracking North Pacific Humpback Whales To Unravel Their Basin-Wide Movements. Final Technical Report. Prepared for Pacific Life Foundation. Marine Mammal Institute, Oregon State University. Newport, Oregon, USA. 30 June 2019. 58 pp. doi:10.5399/osu/1117. https://ir.library.oregonstate.edu/concern/technical_reports/z890s0924.

Salden, D. R., L. M. Herman, M. Yamaguchi, and F. Sato. 1999. Multiple visits of individual humpback whales (Megaptera novaeangliae) between the Hawaiian and Japanese winter grounds. Can. J. Zool. 77(3):504-508.

Taylor, B.L., K.M. Martien, F. Archer, K. Audley, J. Calambokidis, T. Cheeseman, J. De Weerdt, A. Frisch Jordán, P. Martínez- Loustalot, C.D. Ortega-Ortiz, E.M. Patterson, N. Ransome, P. Ruvelas, and J. Urbán R. In review. Evaluation of Humpback Whales Wintering in Central America and Southern Mexico as a Demographically Independent Population. U.S. Dep. Commer., NOAA-TM-NMFS-SWFSC-xxxxx, xx p.

Titova, O.V., O.A Filatova, I.D. Fedutin, L.S. Krinova, A.E. Burdin, E. Hoyt. 2019. Movements of humpback whales (*Megaptera novaeangliae*) between feeding aggregations in the Far Eastern seas and the migration links with breeding grounds. Marine Mammals of the Holarctic 1: 322-3277. doi: 10.35267/978-5-9904294-0-6-2019-1-322-328.

Wade, P.R. 2021. Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas. Paper SC/68c/IA03 submitted to the Scientific Committee of the International Whaling Commission.

Wade, P.R., T.J. Quinn II, J. Barlow, C.S. Baker, A.M. Burdin, J. Calambokidis, P.J. Clapham, E. Falcone, J.K.B. Ford, C.M. Gabriele, R. Leduc, D.K. Mattila, L. Rojas-Bracho, J. Straley, B.L. Taylor, J. Urbán R., D.Weller, B.H. Witteveen, and M. Yamaguchi. 2016. Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas. Paper SC/66b/IA21 submitted to the Scientific Committee of the International Whaling Commission, June 2016, Bled, Slovenia.

Table 1. -- Photographic ID matches between wintering areas within Hawaiʻi from the 2004-2006 SPLASH project (from Table 5 in Calambokidis et al. 2008). Values on the diagonal represent the number of unique IDs from the specific breeding area over the course of the SPLASH effort.

SPLASH Strata	**Kauai**	**Oahu**	**Penguin Bank**	**Molokai**	**Maui**	**Hawaiʻi Island**
Kauai	203	1	0	4	29	2
Oahu		89	0	5	20	9
Penguin Bank			34	3	4	3
Molokai				201	61	12
Maui					1526	99
Hawaiʻi Island						507

Table 2. -- Photographic ID matches between winter and summer areas from the 2004-2006 SPLASH project (from Table 10 in Calambokidis et al. 2008). WGAO – western Gulf of Alaska, NGOA – northern Gulf of Alaska, SEAK – Southeast Alaska, NBC – northern British Columbia, SBC – southern British Columbia, NWA – northern Washington, CA – California, OR – Oregon, Phil – Philippines, OK – Okinawa, OG – Ogasawara, MX – Mexico, Rev – Revillagigedos, ML – mainland, Cent Am – Central America.

	Winter	**Asia-Phil**	**Asia-OK**	**Asia-OG**	**Hawai'i**	**MX-Rev**	**MX-Baja**	**MX-ML**	**Cent Am**
Summer	**Unique IDs**	77	215	294	2317	562	406	690	105
Russia	102	6	14	5	4	1	0	0	0
Aleutians	63	0	1	0	4	0	2	0	0
Bering	491	0	1	5	44	11	8	11	0
WGOA	301	0	0	2	26	13	7	4	0
NGOA	1038	0	0	1	124	44	20	21	0
SEAK	1115	0	0	0	215	9	3	8	0
NBC	583	0	0	0	99	8	5	4	0
SBC-NWA	207	0	0	0	20	2	8	22	3
CA-OR	525	0	0	0	0	0	20	97	26

Table 3. -- Photographic ID matches between summer areas in 2004 and 2005 during the SPLASH project (from Table 8 in Calambokidis et al. 2008). WGOA – western Gulf of Alaska, NGOA – northern Gulf of Alaska, SEAK – Southeast Alaska, NBC – northern British Columbia, SBC – southern British Columbia, NWA – northern Washington, CA – California, OR – Oregon.

	2005	**Russia**	**Aleut-Bering**	**WGOA**	**NGOA**	**SEAK**	**NBC**	**SBC-NWA**	**CA-OR**
2004	**IDs**	72	301	111	427	482	236	152	319
Russia	40	10	0	0	0	0	0	0	0
Aleut-Bering	291	0	41	0	0	0	0	0	0
WGOA	223	0	0	33	1	0	0	0	0
NGOA	730	0	0	6	119	1	0	0	0
SEAK	808	0	0	0	4	175	16	0	0
NBC	421	0	0	0	0	13	74	4	0
SBC-NWA	76	0	0	0	0	0	1	21	1
CA-OR	252	0	0	0	0	0	0	1	47

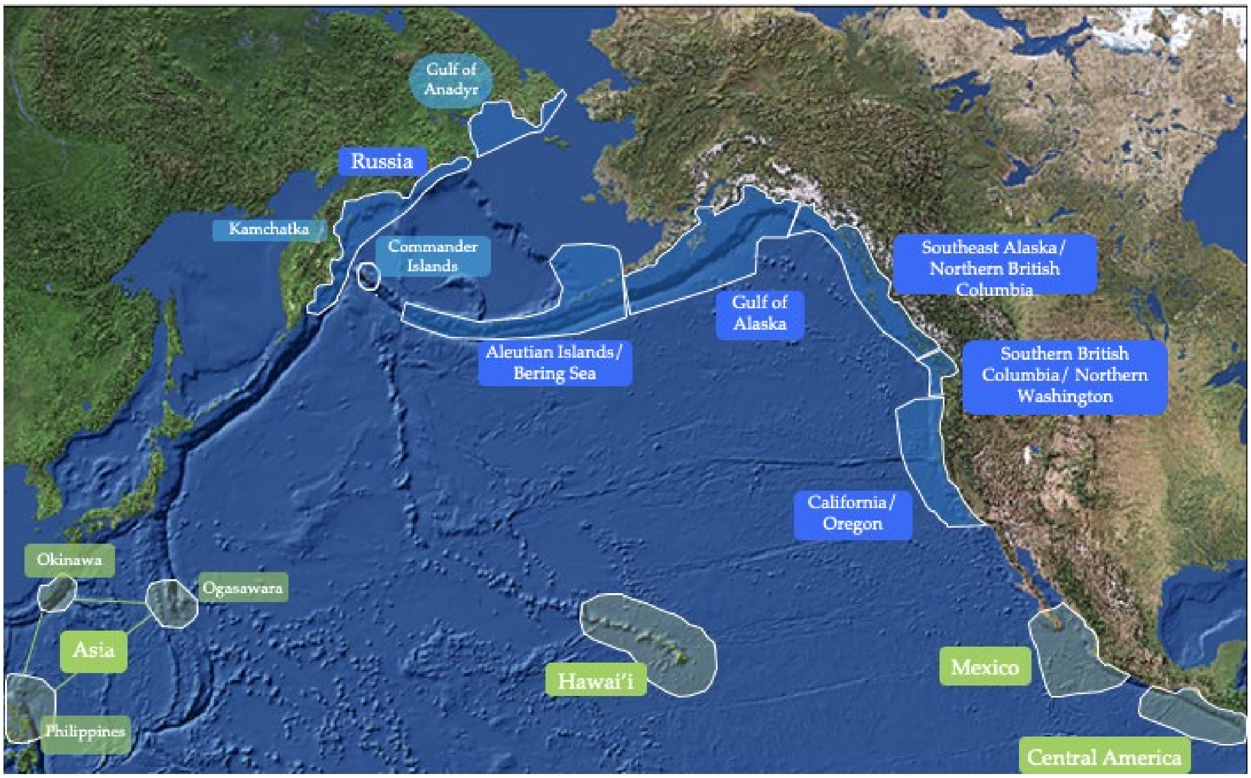

Figure 1. -- Regional strata for the analysis in Wade (2021), with summer areas labeled in blue and winter areas labeled in green. Sub-regions in Russia and Asia are also labeled in lighter and more transparent blue or green. The polygons roughly enclose where survey effort occurred for each area.

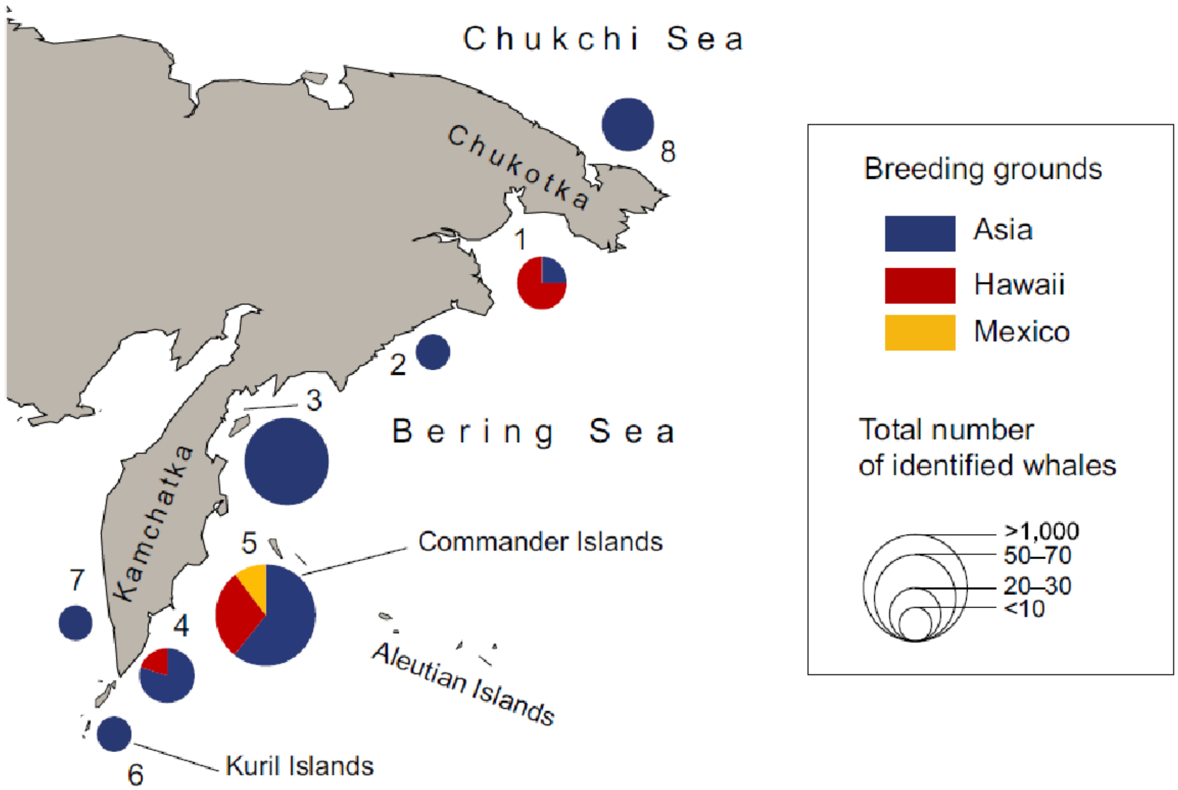

Figure 1. -- Match rates between Russian feeding areas and North Pacific breeding areas (figure 1 from Titova et al. 2018). The numbers on the map represent specific sampling areas: 1- Anadyr Gulf, 2- Koryak coast, 3- Karaginsky Gulf, 4- eastern Kamchatka coast, 5.

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