Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration

HAWAIIAN ISLANDS HUMPBACK WHALE NATIONAL MARINE SANCTUARY

Trends in Humpback Whale *(Megaptera novaeangliae)* Abundance, Distribution, and Health in Hawaiʻi and Alaska

Report from a meeting held on November 27–28, 2018

NOAA National Ocean Service
Office of National Marine Sanctuaries
Hawaiian Islands Humpback Whale National Marine Sanctuary

NOAA National Marine Fisheries Service
Pacific Islands Regional Office
Protected Resources Division

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Note
The findings and recommendations presented in this report are those of the meeting participants and do not necessarily reflect the policies or positions of NOAA or the Department of Commerce.

Cover Photo
A NOAA team documents a humpback whale surfacing in the Hawaiian Islands Humpback Whale National Marine Sanctuary near the West Maui Mountains in Hawaiʻi.
Credit: NOAA HIHWNMS under NOAA permit #15240

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This meeting convened key researchers and managers involved in studies examining recent trends in humpback whale abundance, distribution, and health in Hawaiʻi and Alaska. The objectives of the meeting were the following:

1. Present data that speak to reported changes in humpback whale sighting rates over the past 3-4 years.
2. Consider potential explanations for the observed trends.
3. Identify knowledge gaps and establish research priorities for filling those gaps.
4. Evaluate strategies and establish a consensus on a way forward.

Workshop participants presented data from boat-based transect surveys, boat-based photo-identification efforts, shore-based controlled scans using theodolite technology, and shore-based citizen science counts. The results indicated an overall reduction in sighting rates of humpback whale calves and non-calves from Southeast Alaska, Prince William Sound, Hawaiʻi Island, and Maui over the last 4-5 years. These findings were consistent with data from Passive Acoustic Monitoring (PAM) recorders off Maui indicating a significant reduction in sound pressure levels of the chorusing of humpback whales over the same period. However, systematic data are lacking to assess humpback whale trends in other areas of the Hawaiian Islands and the Pacific. Participants also presented data showing a correlation between whale reductions and environmental factors such as a strong El Nino, a warming "blob" and a negative Pacific Decadal Oscillation (PDO) current. Several hypotheses were proposed to help explain reduced whale counts, including nutritional stress, changes in distribution, human impacts, and natural cyclical variability.

The group identified the various knowledge gaps and then discussed the types of research efforts that would be needed to address these gaps. These knowledge gaps and associated research efforts were then ranked in order of priority based on perceived need and feasibility. The top five research priorities are listed below with the understanding that the remaining knowledge gaps should not be neglected.

- Distribution of whales - Improve existing knowledge about humpback whale habitat use to determine whether lower numbers of whales observed indicates a shift in breeding and/or feeding habitat use. Do this via leveraging existing datasets and pursuing new studies.
- Population health - Increase assessment of humpback whale body condition and health using morphometrics and biomarkers over a broad geographic scale to assess whether health is a factor in decreased sightings.

- Demographics/Trends - Determine whether humpback whale abundance, reproduction, and survival rates have changed over time in breeding and feeding areas, and whether the apparent recent changes are beyond what one would expect from a population at equilibrium or "carrying capacity."
- Prey distribution and quality - Investigate potential changes in quality, quantity, and distribution of food sources to address the hypothesis that nutritional stress is a factor that is affecting humpback whale demography, habitat use, health, and behavior.
- Environmental and Anthropogenic drivers - Investigate the role of environmental and anthropogenic factors in all of the above, including oceanographic conditions, climatic conditions, and land/sea connections, as exemplified by the Kumulipo in Hawai'i and the OneHealth concept.

The group discussed various strategies that would help accomplish these research priorities. One common thread and a main theme of the meeting overall was collaboration. Many of the strategies emphasized the need for all parties to collaborate and coordinate their efforts. This included parties outside the workshop such as researchers, managers, cultural practitioners, and others from other regions, as well as globally.

Moving forward beyond the meeting, there was a consensus among participants that there should be continued efforts to engage with one another on various levels. It was agreed that this would be accomplished via periodic conference calls that would be used to provide updates from various field efforts, and through the formation of working groups that would address specific priority issues identified at the meeting (see section IX for a list of working groups identified on a follow-up call).

II. INTRODUCTION

Objectives

This report is a summary of a meeting held on November 27-28, 2018 in Honolulu, Hawaiʻi that convened key researchers and managers involved in studies examining trends in humpback whale abundance, distribution, and health in Hawaiʻi and Alaska. The objectives of the meeting were the following:

1. Present data that speak to reported changes in humpback whale sighting rates over the past 3-4 years.
2. Consider potential explanations for the observed trends.
3. Identify knowledge gaps and establish research priorities for filling those gaps.
4. Evaluate strategies and establish a consensus on a way forward.

The meeting agenda in Appendix A outlines the steps taken to achieve the objectives, and Appendix B provides a list of attendees.

Background

Humpback whales worldwide were hunted to the brink of extinction due to heavy commercial whaling during the first six decades of the 20th century. North Pacific humpback whales were reduced to less than 10% of their pre commercial whaling abundance estimate of 15,000 whales, and were the last major population of humpbacks to receive international protection by the International Whaling Commission (IWC) in 1966 (Rice, 1978, Johnson & Wolman, 1984). Under the protections of the IWC commission, the U.S. Endangered Species Act, the U.S. Marine Mammal Protection Act, North Pacific humpback whales have experienced a steady recovery of their numbers and in conjunction with this have in some regions expanded their habitat footprint (e.g. see Mobley et al. 2001; Lammers et al. 2011).

The Hawaiian Islands are the principal breeding grounds for North Pacific humpback whales. In spring and summer months, the majority of these whales migrate to Southeast Alaska, the Gulf of Alaska, and Northern British Columbia (Calambokidis et al. 2008). The most recent estimate of humpback whale abundance in Hawaiʻi was based on a multi-nation, multi-research group North Pacific photo-identification study termed "SPLASH" (Status of Populations, Levels of Abundance and Structure of Humpback Whales) from 2004-2006. That effort revealed an estimated 21,808 humpbacks in the North Pacific, 10,103 (excluding calves) of which were estimated to migrate to Hawaiʻi and were considered a distinct population segment (Barlow et al. 2011; Calambokidis et al. 2008). SPLASH also estimated an annual increase in humpback whale abundance of 6% (Calambokidis et al. 2008), a figure that agreed with the 7% calculated earlier by Mobley et al. (2001) based on aerial survey data. Based on the results of the SPLASH study and a review of humpback populations worldwide, NOAA in 2016 issued a ruling delisting the Hawaiʻi DPS of humpbacks from its endangered status.

Early in the 2015-2016 humpback whale breeding season in Hawaiʻi, tour companies on the island of Hawaiʻi began reporting lower numbers of humpback whales than expected for that time of year. This was initially thought to represent a patchy distribution across the islands or a delayed arrival. However, as the season progressed and additional reports were received from tour operators, fishermen, and researchers from other islands, the trend of fewer sightings throughout the islands continued. Similar reports of low sighting rates of humpback whales were received from parts of their breeding/calving grounds off Mexico.

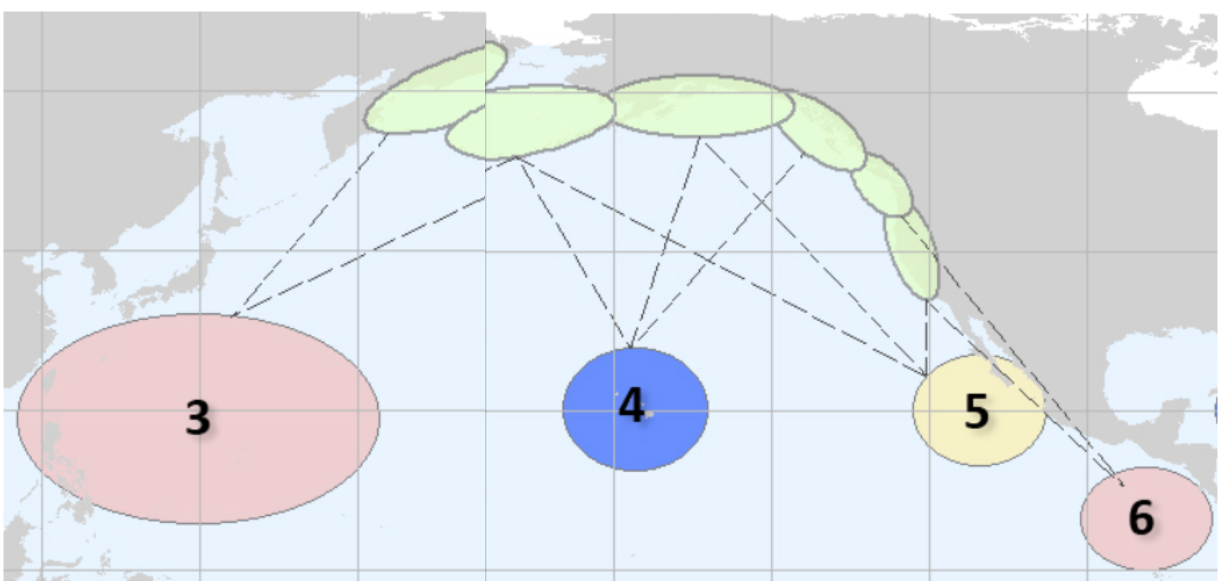
Several researchers were able to quantify these observed changes through existing long-term transect and shore station surveys as well as acoustic monitoring (Cartwright, Gabriele, Goodwin; pers. comms.). Some researchers in Alaska (Gabriele and Neilson, Moran; pers. comms.) and Hawaiʻi (Gabriele and Cartwright; pers. comms.) had been seeing a trend of decreased sightings and lower calf production in their respective efforts starting as early as 2013. In Alaska, observations of emaciated animals and changes in distribution (i.e., habitat use) were also being noted. Other researchers noticing these changes, shifted and expanded their efforts (e.g., SPLISH - Survey of Population Level Indices for Southeast Alaska) to better understand and quantify the observed trends (Cartwright, Currie, Stack, Frankel, Gabriele, Kuegler, Moran, Lammers, Lyman, Straley, Sharpe, Szabo).

As changes continued to be observed and quantified over the following seasons, research efforts continued to investigate the trends and determine possible causal factors. Working hypotheses were posed involving food resources, broader environmental changes, carrying capacity, changes in habitat usage/distribution patterns, human impacts, health indicators, survivorship, and productivity. While many researchers, managers, and stakeholders collaborated and shared information towards evaluating these hypotheses, more discussion, planning, and coordination were required.

Management of humpback whales in Hawaiʻi and Alaska is the responsibility of NOAA within the U.S. Department of Commerce. Specifically, NOAA's National Marine Fisheries Service, Office of Protected Resources is responsible for marine mammals under the Endangered Species Act (ESA) and the Marine Mammal Protection Act. In 2016, NOAA divided humpback whales world-wide into 14 Distinct Population Segments (DPSs) with five of these continuing to be listed under the ESA and the other nine no longer on the list. Humpback whales that breed and calve in Hawaiʻi fell into the latter category. However, delisting did not end the obligations of NOAA to manage the populations that came off the list including the Hawaiʻi DPS. A Post-delisting Monitoring Plan is required to monitor changes in population status, trends, and threats for a minimum of five years (or longer for a long-lived species such as humpback whales) to ensure that it remains healthy and doesn't "backslide" without the protections of the ESA. A Post-delisting Monitoring Plan was developed in 2016 -- in collaboration with some who were present at this meeting -- that has three primary goals:

1. Monitor each DPS to detect changes in trends in the production of calves, adult/juvenile abundance and population growth rates, and distinguish whether changes are a threat to the DPS or a signal that the DPS is approaching or has surpassed carrying capacity;
2. Monitor the DPSs to detect changes in spatial and temporal distribution; and
3. Monitor residual or emerging threats, and identify new threats that could affect the sustainability of the recovery of the humpback whale DPSs.

The Post-delisting Monitoring Plan contains a list of "response triggers" that act as indicators of specific concerns of any non-listed humpback whale DPS (e.g., significant decline in abundance or range, decline in birth or survival rates, changes in spatial or temporal distribution, new threats or changes in existing threats, or decline in a specific health factor). If monitoring data or other substantial information indicates that one of these response triggers has been reached, the plan calls to convene an ad hoc team of experts to advise the agency on what to recommend as subsequent management actions. These recommendations can include a range of actions, such as enhancing monitoring efforts, extending the monitoring period, initiating a regional status assessment or ESA status review, or implementing an emergency listing of the DPS. The purpose of this meeting was to act as a preliminary evaluation of concerns expressed by members of the wildlife conservation and research communities, and the information in this report will likely support future implementation of the humpback whale Post-delisting Monitoring Plan.



This map shows the DPS for humpback whales that are found in Alaska and Hawaiʻi (3-Western North Pacific DPS, endangered; 4-Hawaiʻi DPS, not at risk; 5-Mexico DPS, threatened; 6-Central America DPS, endangered. The green (unnumbered) areas are feeding areas, with the dashed lines showing habitat linkages).

III. PRESENTATIONS

A series of presentations by Hawai‘i-based and Alaska-based humpback whale researchers were provided to lay the foundation of knowledge for the meeting and create a common framework for discussing observed trends and hypotheses. The first set of presentations were from researchers whose primary work was on humpback whales in Hawai‘i during the breeding season. This was followed by presentations by researchers whose research spanned both the breeding and feeding areas. The last set of presentations were from researchers based in the feeding areas and provided an Alaska perspective of humpback whale population dynamics. There was broad agreement across the presentations that multiple lines of empirical evidence support observations of lower numbers of whales in both Hawai‘i and Alaska over the past 3-5 years. Presentations were limited to 10 minutes with 5 minutes for questions and clarifications. The abstracts, which summarize each presentation, are located in the attached Appendix C.

Presentations on research in Hawai‘i:

1. *Recent declines in sighting rates of mother-calf pairs within a favored breeding region used by Hawai‘i's Distinct Population Segment of humpback whales.*
   Rachel Cartwright, Keiki Kohala Foundation
2. *Changes in humpback abundance 2001-2018: Climate driven?*
   Adam Frankel, Hawai‘i Marine Mammal Consortium
3. *Trends in humpback whales observed in Maui Nui between 2012-2018.*
   Jens Currie/Stephanie Stack, Pacific Whale Foundation
4. *Trends in male humpback whale song chorusing off Maui, Hawai‘i since 2014/2015.*
   Anke Kuegler, University of Hawai‘i
5. *Hawaiian Islands Humpback Whale National Marine Sanctuary monitoring: Some associated trends.*
   Ed Lyman, NOAA, Office of National Marine Sanctuaries

Presentations on research encompassing Hawai‘i and Alaska:

6. *Winter HICEAS 2019 and contributions of the PIPAN dataset to examining humpback whale trends.*
   Erin Oleson/Ann Allen, NOAA Pacific Islands Fisheries Science Center
7. *Developing a bioenergetic model for humpback whales by assessing their body condition across their Alaskan feeding grounds and Hawaiian breeding grounds.*
   Lars Bejder, UH Hawai‘i Institute of Marine Biology
8. *Movements and Habitat Use of Humpback Whales Satellite-tagged in Hawai‘i (1995-2018).*
   Bruce Mate/Daniel Palacios, Oregon State University

Presentations on research in Alaska:

9. *Recent population level changes in Glacier Bay and Icy Strait humpback whales.*
   Chris Gabrielle, National Park Service
10. *Ecosystem implications for the decline in reproductive success in humpback whales in the Gulf of Alaska.*
    Jan Straley, University of Alaska Southeast

IV. HYPOTHESES

Having established a common point of reference through the presentations, the group brainstormed and discussed potential hypotheses to explain observed trends. It was noted that any number of hypotheses could overlap or be tied together. The outcome of these conversations are captured below in Table 1, and some of the raw notes from the meeting are found in Appendix D. Although numerous proximate explanations were proposed as hypotheses, all of these ultimately relate back to some type of change in the environment of humpback whales. Under this broad umbrella, the following working hypotheses were formulated by the group.

Nutritional Stress

An overarching hypothesis for the observed declines in humpback whale numbers is that they are being impacted by nutritional stress. This could result from numerous causes, both direct and indirect, and these causes may overlap and be working in conjunction with each other and other causes. Among the potential direct causes that need to be investigated are 1) prey quantity and quality (lipid content), 2) prey advection (movement/relocation, i.e., krill biomass may have moved offshore), 3) prey recruitment or lack thereof, 4) competition for prey with other species, 5) competition for prey with fisheries, and 6) compromised reproduction or reproductive failure. Among the potential indirect causes, especially for 1-3 above, are effects of ocean acidification (e.g., effects on plankton and the food chain), and ocean warming (potentially linked to pathogens and harmful algal blooms).

It was noted that there is less research monitoring in Alaska than Hawai‘i (although it's not comprehensive in Hawai‘i either), and that there is a need to determine whether all the indices are trending downward or whether things may be improving in some areas while declining in others. Within the context of these issues, there was discussion about noted changes in southeast Alaska's ecosystem, such as birds dying off, fisheries being reduced, and fewer humpbacks whales being seen; yet, increases in humpback whales sightings in British Columbia and the Eastern Pacific were also mentioned. As such, it was concluded that the situation needs to be examined at the global (or basin) scale.

Change in Distribution

Another hypothesis that was discussed is a change in the spatial and/or temporal distribution of humpback whales, which may account for the reduction of sightings in areas of traditionally high abundance. It was noted that this could be either independent from or caused by nutritional stress. It is possible that humpback whales are using other breeding areas. For instance, monitoring of breeding whales is currently focused on the main Hawaiian Islands (MHI) only; it's possible that some of the whales may have moved to the Northwestern Hawaiian Islands (NWHI) or elsewhere. Information on the use of the NWHI by humpback whales is still poorly documented. Some acoustic data have been collected, but not all have been analyzed. However, there are plans to increase acoustic research in this area as well as the area around Wake Island (see discussion in Knowledge Gap below). It was further noted that there may be a link with Mexico, i.e., maybe at a given time there are more whales in one breeding area and fewer in the other (this would also indicate that the DPSs aren't as distinct from one another as presently assumed). Other reasons for a possible or perceived change in distribution are as follows: 1) whales are overwintering in Alaska more, 2) they're not finishing their migration to Hawai‘i, and 3) they're migrating but spending less time in Hawai‘i. Any of these could be due to lack of fitness from nutritional stress. Information to support a change in whale distribution over a broad geographic range would be needed to distinguish a distribution shift from a reduction in numbers in the comparatively small areas where the declines were documented.

Human Impacts
Although the hypotheses above may be caused, directly or indirectly, by humans, a number of other human impacts could also be affecting humpback whale populations. These include pollutants, such as heavy metals, plastics, PCBs and other man-made chemicals; habitat degradation, due to such things as underwater noise and vessel traffic; entanglements; and disturbance, including disturbance caused by commercial activities, such as tourism.

Natural Cyclical Variability and Unknown Factors
While discussing the previously listed hypotheses, it was noted that natural cyclical variability in the population and environment should also be considered. In other words, could factors such as carrying capacity be affecting the whale population, which had been growing steadily for decades? Could harmful algal blooms (HABs) be affecting prey or whale health? Are broader climate patterns or changes such as El Niño-Southern Oscillation (ENSO) and/or the Pacific Decadal Oscillation (PDO) have an affect? Might an undetected pathogen or disease be compromising whale health? These and potentially other factors not yet thought of by the group were flagged as meriting further discussion.

Table 1. Potential hypotheses to explain observed trends

Hypotheses and Potential Causes/Factors
Nutritional Stress
• Lack of prey quantity and quality (lipid content). • Ocean acidification affecting plankton. • Climate change/ocean warming. • Decrease in prey recruitment. • Decrease in prey availability due to movement or relocation (either e.g. depth, offshore, etc.) • Competition for prey w/ other species. • Competition for prey w/ fisheries.
Change in Distribution
• Not finishing migration • Increased use of Northwestern Hawaiian Islands • Going to waters near Mexico • Less time in main Hawaiian Islands • Shifts to different parts of Alaska • Shifts to British Columbia
Human Impacts
• Heavy metals and plastics • PCBs and other man-made chemicals • Habitat degradation
Natural Cyclical Variability and other factors
• Population carrying capacity • Harmful algal blooms • Natural pathogens • Other, still unknown, factors influencing whale behavior, health or survival

V. KNOWLEDGE GAPS

After the discussion of the hypotheses that could help explain the observed changes in humpback whale numbers, the participants turned their attention to defining the gaps in knowledge that presently exist for understanding the causal factors behind the observed trends. The group first listed the various perceived gaps and then discussed the types of research efforts that are needed to address these gaps. At the end of the session, the group was asked to rank the knowledge gaps and associated research efforts in order of priority based on perceived need.

During the discussion, multiple knowledge gaps were identified that ranged in subject and scope. These can be summarized by the following questions:

- Are the observed trends cyclical in nature? In other words, is there evidence of past reductions in humpback whale numbers reflecting a periodic pattern of variability?
- Are humpback whales occurring further offshore, for example near sea mounts?
- Besides the known breeding and feeding areas in Hawaiʻi and Alaska, where else are whales from the Hawaiʻi DPS going? Are "missing" whales going elsewhere?
- Has the overall health of humpback whales in the population declined?
- How/where are humpback whales from the Hawaiʻi DPS interacting with other north Pacific DPSs? Are other north Pacific DPSs also experiencing changes in numbers or distribution?
- Have population parameters (pregnancy rates, calf production and mortality, age structure, etc.) changed for the Hawaiʻi DPS?
- Has prey availability and/or quality changed? Have whales had to switch to different prey and/or look for prey in new places?
- Are data pointing to broader climatic (El Nino, PDO, etc.) or ecosystem (acidification, algal blooms, etc.) changes that would have resulted in humpback whales being affected?
- Are anthropogenic risk factors (noise pollution, habitat degradation, entanglements, vessel collisions, etc.) contributing to the observed changes in the number and distribution of humpback whales, or could these very changes be affecting the rate and impact of anthropogenic risk factors (e.g. changes in entanglement rate due to change in habitat usage)?

Having defined the major knowledge gaps, the group listed research methods that could help fill the gaps and organized these into a table that combines specific knowledge gaps with potential research efforts. At the end of this session, which was also the end of the first day of the meeting, participants individually ranked the knowledge gaps/research needs (gaps/needs) in order of priority on a scale of lowest (1) to highest (5) priority via a questionnaire. In addition, participants were asked to rate their overall level of concern about the recent observed changes in whale numbers on a scale of no concern (1) to high concern (5). See Appendix E for the Knowledge Gap priority ranking and the wording used on the questionnaire.

The results from the ranking of gaps/needs are detailed in Table 2. The top five gaps/needs identified, in descending order, were:

1. Developing a better understanding of the distribution of humpback whales.
2. Obtaining health metrics for the population.
3. (tie) Establishing demographic trends for the population.
3. (tie) Understanding changes in prey distribution/abundance and whale foraging behavior.
4. Determining the environmental factors that are driving the observed changes.

During the beginning of the second meeting day, the group decided that, although the five lower ranked gaps/needs were also important, given limited meeting time and resources for implementing research priorities, further discussions about research strategies should focus primarily on the top five gaps/needs.

Table 2. Prioritized knowledge gaps and research needs

Rank	Knowledge gaps	Means of addressing / type of research
1	**Distribution of Whales:** • Where do they go to breed, feed? • Are they offshore / how much are they using seamounts? • Where are Southeast Alaska and Prince William Sound whales? • Where are Hawai'i whales?	• Tagging • Photo-ID (compare existing catalogs and collect in more areas) • Acoustics • Remote sensing (wave gliders, satellites, fixed-wing UAVs, etc.), platform of opportunity for data collection • Aerial surveys (density, redistribution; in NWHI, at Cross Seamount, and other close seamounts)
2	**Population Health:** • Development of a health assessment protocol • Combine with 8) Ecosystem Health (reach out to NWFSC)	• Bio samples for biomarker analysis (stomach content, blubber, reproductive tract, respiratory vapor, stress hormones) • Morphometrics (linking photos to UAV measurements to compare with historic data; also increase available data) • Historical stranding data
3	**Demographics/ Trends:** • Population parameters • Age structure • Numbers • Productivity • Reproductive patterns • Vital rates	• Leveraging existing catalogs (Happy Whale) • UAVs to determine age structure • Blubber biopsies to determine pregnancy rates • Determining calving intervals w/ database • Reproducing a mini-SPLASH -- aerial surveys, reproductive hormones, updated calf mortality rates
4	**Prey distribution and quality:** • Change in prey availability and/or distribution • How prey relates to fisheries • Prey quantity & quality	• Identify shift in diet using stable isotopes • Fisheries catch data • Chlorophyll levels • Hydroacoustic surveys • Net / trawl surveys • Modeling of prey • Comparative analyses • Prey composition analysis

Rank	Knowledge gaps	Means of addressing / type of research
5	**Environmental drivers:** Chlorophyll, salinity, SST, CO2, oceanographic events (PDOs), acidification	• Meta analysis & modeling as they relate to observed trends (hypothesis-driven at the appropriate scale) • Combine different data sources to augment predictive power
6	**Compare Hawai‘i DPS and other North Pacific populations**	• Consultation w/ experts from other DPSs
7	**New prey base?** • Are they using new / different prey?	• Stable isotopes (fecal / blubber / baleen) analysis • SPLASH data (as comparison) • Workshop to leverage info from fishermen, etc. (need to give them cameras for proof; get buy-in from them)
8	**Ecosystem health:** • Domoic acid/saxitoxins/ trophic cascade	• Monitor through the food chain (e.g., crustaceans) • Coordinate with public health researchers (HAB lab in Sitka)
9	**Anthropogenic risk factors:** • Vessel collisions • Noise • Tourism, plastics, pollution • Oil spills • Entanglement • Habitat degradation (development / construction)	• Entanglement rates • Necropsy records • Scar analysis • Behavioral analysis (tourism effects) • Underwater sound monitoring • Toxicology • AIS monitoring • Measure • Necropsies / stomach content analysis • Risk factor that encompasses all these risks • Encounter model • Ear wax plugs
10	**Interactions among the various populations**	• Sat tags • Photo-ID • Song characteristics • Genetics • Meta-analysis from other populations • Population modeling to explore questions to ask

VI. STRATEGIES

Having identified and prioritized the major knowledge gaps and the means to address them, participants discussed over-arching strategies towards their implementation. Beyond prioritization based on perceived need, it was acknowledged that some hypotheses (e.g., the question of a declining population vs. one undergoing habitat shift) needed to be prioritized as they related to other hypotheses. The cost of different research strategies was also brought up with regard to how it might influence execution and priorities. However, it was also emphasized that there are costs associated with the loss of the species. Humpback whales, Koholā, provide significant biological (e.g., energetic input), cultural (e.g., integration with Native Hawaiian and Native Alaskan culture), and economical (e.g., tourism) value. It was recommended that these costs should be outlined to illustrate the different impacts and help garner additional support (i.e., funding).

While some research strategies had been broached earlier, others were introduced and fell into several broad categories, including temporal, spatial, procedural, and biological. "Temporal strategies" included the use of past (e.g. SPLASH), present (e.g. SPLISH), and, in most cases, expanded and collaborative future efforts (e.g., a mini – SPLASH). The Post Delisting Management Plan for the central North Pacific DPS of humpback whales also emphasized the strategy of utilizing existing resources collaboratively to address research, monitoring, and management needs in the future.

"Spatial strategies" addressed local, regional, and global aspects of the effort, including areas missed or that otherwise represented unknowns. Areas mentioned for expanded work included the Aleutians, Northern Alaska, Western Gulf of Alaska, Prince William Sound, British Columbia and the Salish Sea, Northwestern Hawaiian Islands, and a number of seamounts. Increased collaboration with Mexico and Canada, and closer investigation of populations found there, as well as elsewhere (e.g. North Atlantic), was emphasized and represented examples of increased regional and global scope of effort.

"Technology/data strategies" included the use of technology/tools and associated procedures to help garner information. Some key examples of technology/tools reiterated were the use of fluke ID catalogs to answer such questions as where animals might be going and providing updates on reproductive and recruitment parameters (e.g. calving rates and calf mortality). In order to take advantage of this strategy, fluke catalogs needed to be shared, efforts increased to gain additional fluke IDs, and more automated, cost-effective means of matching needed to be pursued. One means already being used by many researchers and the public that was mentioned was Happy Whale, an algorithm-based matching platform started by Ted Cheeseman. Researchers could combine their fluke catalogs under Happy Whale with MOUs in place to protect their data. Acoustics was also emphasized as a cost-effective means of exploring offshore and more remote regions through mainly humpback whale song presence and signature strength. Satellite tagging was reviewed as an important tool towards determining the habitat use of the animals (i.e., where they were going) and providing predictive habitat modelling. Satellite technology was also mentioned for remote sensing and modelling. Up-and-coming tools, like the use of Unmanned Autonomous Vehicles (UAVs) were discussed towards assessing the condition and health of the animals. Biopsy sampling was reiterated as a means of providing samples for stable isotope studies and prey resources, as well as genetics and steroid hormone analysis, complementing samples already obtained from SPLASH.

“Biological strategies” included looking at the parallels (past and present) in other species as a means of answering questions. A prime example might be the gray whale that has shown various population increases and declines over the years.

One commonly mentioned strategy and a main theme of the overall meeting, was collaboration. Many of the strategies emphasized the need for all parties to collaborate and coordinate their efforts. This included parties outside the workshop such as researchers, managers, cultural practitioners, and others from other regions, as well as globally. The following are examples of collaborative strategies: combining/sharing of fluke ID catalogs, partnering in research efforts such as a Mini-SPLASH or the recent SPLISH effort in Alaska, and past collaborative efforts that could be re-mined for data (e.g. genetics from SPLASH). The topic of collaboration brought up the need for agreements (MOUs), data repositories, and coordination, and it was noted that such efforts were typically cost-effective strategies and interrelated.

VII. MOVING FORWARD

The final guided discussion of the meeting focused on charting a collective path forward. The first topic considered was on the funding sources that might be pursued to implement the research priorities previously outlined.

Funding

Potential sources of support suggested by workshop participants included:

- U.S. Navy via either the Office of Naval Research, the Living Marine Resources program, or the Fleets through the Marine Species Monitoring Program.
- NOAA via the National Marine Fisheries Service or the Office of National Marine Sanctuaries
- National Marine Sanctuary Foundation
- State of Hawaiʻi
- National Science Foundation via a rapid response grant
- Private foundations such as Pacific Life
- Hawaiʻi Tourism Authority and Alaska Travel Industry Association
- Bureau of Ocean Energy Management
- Whale Trust Maui

Two representatives of organizations present at the meeting indicated their willingness to assist with fundraising efforts. Dr. Meagan Jones, representing Whale Trust Maui, stated that her organization would help fundraise via their Whale Tales event, an annual event that raises funds for whale research in Hawaiʻi. In addition, it was agreed that momentum from the meeting should be used to raise funds via the National Marine Sanctuaries Foundation and Shannon Yee volunteered to explore this avenue. Other potential fundraising mechanisms mentioned were a GoFundMe campaign and/or directing donors to a website specifically designed to raise funds for research to support the priorities identified at the meeting.

Communication

Another topic of discussion during this session was communication and the type of messaging that should come out of the meeting. It was agreed that reinforcing the importance of good etiquette around whales, particularly mothers and calves, should be emphasized, given that lower numbers of whales may mean that those whales that are in Hawaiʻi will receive increased attention from the public and commercial operators.

Another recommendation was to explore the cultural connections between whales and native Hawaiians to help inform the causes behind the declining trends in whale abundance. Specifically, the presence of whales in the Kumulipo, the native Hawaiian creation story, was suggested as a resource for documenting the cultural connection between whales and native Hawaiians. In addition, the connectivity between whales and the local fishing community was offered as a messaging point, specifically the large contribution in biomass whales bring to the islands each year and how these ties in to the marine ecosystem.

Finally, it was agreed that talking points should be formulated that capture the main points of consensus among workshop participants regarding the observed trends in whale abundance. It was agreed that these should be general points rooted in what is currently known rather than be speculative. The talking points that were developed are summarized in the conclusion section below.

The last topic of discussion in the session was how the group should move forward beyond the meeting. There was a general consensus that the meeting participants should continue to engage with one another on various levels. One way to do so would be via periodic conference calls that could be used to provide updates from various field efforts on the trends observed. Another way would be through the formation of working groups that would address specific priority issues identified at the meeting, for example the need to have a common catalogue for matching whale fluke IDs across regions. There was agreement on both of these options and a conference call was planned to follow-up on these ideas. Finally, the possibility of another meeting in the following year was discussed to re-evaluate the situation with humpback whales and update the research priorities based on the latest information. There was support for this plan as well, but the details were left open. Among the meeting options mentioned were that 1) a workshop could be organized at the 2019 Biennial Conference of the Biology of Marine Mammals, 2) NOAA in Hawaiʻi could again lead the organization of a second meeting similar to the first one, or 3) participants from the Alaska region could take the lead in organizing another meeting.

VIII. CONCLUSIONS

In summary, various data on recent trends in humpback whale abundance in both Hawaiʻi and Alaska were presented and discussed at this meeting. From these discussions, the participants concluded that whale counts from Southeast Alaska, Prince William Sound, Hawaiʻi Island, and Maui all have shown strong decreases in sighting rates over the last 4-5 years. These trends affect both adults and calves. Acoustic data indicate the number of singing males are decreasing as well, all along the same trends. Trends in other geographical areas are still unclear. The data presented lead to the following questions:

- Are these decreases reflecting changes in habitat use or a population decline?
- What are the broader trends across the entire Hawaii DPS and elsewhere in the North Pacific?
- Are these changes linked to documented declines of other species and/or recent environmental drivers or oceanographic changes?

To answer these questions the group identified the following research priorities:

- Distribution of whales - Improve existing knowledge about humpback whale habitat use to determine whether lower numbers of whales observed indicates a shift in breeding and/or feeding habitat use. Do this via leveraging existing datasets and pursuing new studies.
- Population health - Increase assessment of humpback whale body condition and health using morphometrics and biomarkers over a broad geographic scale to assess whether health is a factor in decreased sightings.
- Demographics/Trends - Determine whether humpback whale abundance, reproduction, and survival rates have changed over time in breeding and feeding areas, and whether the apparent recent changes are beyond what one would expect from a population at equilibrium or “carrying capacity.”
- Prey distribution and quality - Investigate potential changes in quality, quantity, and distribution of food sources to address the hypothesis that nutritional stress is a factor that is affecting humpback whale demography, habitat use, health, and behavior.
- Environmental and Anthropogenic drivers - Investigate the role of environmental and anthropogenic factors in all of the above, including oceanographic conditions, climatic conditions, and land/sea connections, as exemplified by the Kumulipo in Hawaiʻi and the OneHealth concept.

IX. EPILOGUE

As follow-up to the workshop (and as planned at the workshop), the group met via teleconference on December 20, 2018, to discuss the formation of working groups to address many of the top priority data gaps identified in the November meeting. On this conference call, the participants identified membership in and a lead for each working group (see below). Participation in these working groups was not limited to the people at the meeting, i.e., additional names were added in the hopes that others would participate. The groups are open to changing membership, and will meet as they feel necessary and are able.

Working Groups (WG)

Acoustics WG
Adam Frankel, Marc Lammers, Ann Allen, Erin Oleson, Anke Kuegler, Adam Pack, Jessica Chen
Alaska WG
John Moran, Chris, Janet Neilson, Andy Szabo, Jan Straley, Adam Pack, NMML?
Biomarker WG
Lars Bejder, Shannon Atkinson, Adam Pack, Andy Szabo, Christine Gabrielle, Kristi West, Rachel Cartwright, Greg Levine (?) or Michelle Barbieri (?), Kathy B (AK)?, Kate Savage ?
Catalogue WG
Christine Gabrielle, Andy Szabo, Janet Neilson, Jan Straley, Jim Darling, John Moran, Adam Pack, Adam Frankel, Stephanie Stack, Ed Lyman, Rachel Cartwright, Craig Hayslip
Mini-SPLASH WG
Adam Pack, Ed Lyman, Lars Bejder, Stephanie Stack, Jens Currie, Rachel Cartwright, Amanda Bradford, Erin Oleson, Mark Deakos, Jessica Chen, Shannon Atkinson, Craig Hayslip
Morphometrics WG
Lars Bejder, Shannon Atkinson, Rachel Cartwright, Adam Pack, Ed Lyman, Jens Currie, Jan Straley, Andy Szabo, Chris Gabriele, Kristi West, Mark Deakos, Anke Kuegler
NWHI WG
Marc Lammers, Jon Martinez (NOAA PMNM), Shannon Yee, Anke Kuegler, Amanda Bradford, Erin Oleson, Adam Frankel, Adam Pack
Prey / Oceanography WG
John Moran*, Jan Straley*, Andy Szabo, Chris Gabrielle, Rob, Adam Frankel, Janet Neilson, USGS (Yumi?), Daniel Palacios (* Denotes WG lead)
Survey WG
Joe Mobley, Adam Pack, Rachel Cartwright, Mark Deakos, Marc Lammers, Anke Kuegler, Amanda Bradford, Erin Oleson
Tagging WG
Bruce Mate, Daniel Palacios, Ed Lyman, Marc Lammers, Jessica Chen, Mark Deakos, Elizabeth Henderson (Navy)

APPENDIX A - Literature Cited

Barlow, J., Calambokidis, J., Falcone, E.A., Baker, C.S., Burdin, A.M., Clapham, P.H., Ford, J.K.B., Gabrielle, C.M., LeDuc, R., Mattila, D.K., Quin II, T.J., Rojas-Bracho, L., Straley, J.M., Taylor, B.L., Urban-R ,J., Wade, P., Weller, D., Witteveen, B.H. and Yamaguchi, M. (2011) Humpback whale abundance in the North Pacific estimated by photographic capture-recapture with bias correction from simulation studies. Marine Mammal Science 27:793-818.

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APPENDIX B - Meeting Agenda

Trends in humpback whales meeting
AGENDA

Objectives:
This meeting seeks to convene key researchers and managers involved in studies examining recent trends in humpback whale abundance, distribution and health in Hawaiʻi and Alaska. The objectives of the meeting are the following:

1. Present data that speak to reported changes in humpback whale sighting rates over the past 3-4 years
2. Consider potential explanations for the observed trends
3. Identify knowledge gaps and establish research priorities for filling those gaps
4. Evaluate strategies and establish a consensus on a way forward

AGENDA: DAY 1 - November 27th	
Time	**Agenda item**
9:00am HST	*Welcome and Background* ● Welcome participants, introductions, present the purpose of the meeting and review agenda – Marc Lammers ● Provide background – Ed Lyman/Susan Pultz
9:15am HST	*Presentations from Hawaiʻi Researchers (Moderator: Marc Lammers)* ● 15 min each - 10 min presentation and 5 min for *clarifying* Q&A ○ Rachel Cartwright – Keiki Kohala Foundation ○ Adam Frankel – Hawaiʻi Marine Mammal Consortium ○ Jens Currie/Stephanie Stack – Pacific Whale Foundation ○ Anke Kuegler - University of Hawaiʻi ○ Ed Lyman - HIHWNMS
	10:30 HST – Break (15 minutes)
10:45am HST	*Presentations from Hawaiʻi/Alaska Researchers (Moderator: Susan Pultz)* ○ Erin Oleson/Ann Allen – PIFSC o Lars Bejder – Hawaiʻi Institute of Marine Biology o Bruce Mate/Dan Pelacios – Oregon State University o Chris Gabrielle – National Parks Service o Jan Straley – University of Alaska Southeast
12:00pm HST - Lunch (1 hour)	
1:00pm HST	*Guided discussion / Brainstorming session on potential hypotheses to explain observed trends (Moderator: Ed Lyman)* ● List all viable hypotheses to explain observed trends ● Which are supported by the available data? ● Which are unsupported by the available data? ● Which need additional data to be resolved? ● Are observed trends a concern?

	2:45 HST – Break (15 minutes)
3:00pm HST	*Guided discussion / Brainstorming session to identify knowledge gaps and prioritize research needs (Moderator: Marc Lammers)* ● Where do knowledge gaps currently exist? ● Which knowledge gaps are of highest priority to be resolved? ● What types of research efforts are needed to address these gaps? ● Rank potential research efforts based on need, logistics, costs, etc.
5:00pm HST	*Day 1 Wrap-up and Adjourn*
6:00pm HST	*Pau Hana at La Mariana (50 Sand Island Access Rd, Honolulu)*

AGENDA: DAY 2 – November 28th	
9:00am HST	*Welcome* ● Welcome participants, review agenda.
9:05am HST	*Recap* ● Overview of the knowledge gaps and research needs identified on Day 1 ● Group to discuss any overnight reflections or edits
9:30pm HST	*Guided discussion / Brainstorming session on strategies to meet identified research needs (Moderator: Ed Lyman)* ● Should research efforts be coordinated? If so, how? ● Identify potential collaborations and/or synergistic efforts ● Are there data sharing opportunities?
	10:45 HST – Break (15 minutes)
11:00am HST	*Guided discussion / Brainstorming session on ways to move forward (Moderator: Susan Pultz)* ● Where will funds come from to implement research priorities? ● Should a follow-on meeting take place on this topic?
12:30pm HST - Lunch (1 hour)	
1:30pm HST	*Summary/Wrap-up (Moderator: Marc Lammers)* ● Revisit any outstanding discussion topic(s) ● Review the major conclusions from the meeting ● Review responsibilities for meeting report
3:00pm HST	*Day 2 Adjourn meeting*

List of acronyms:
HIHWNMS – Hawaiian Islands Humpback Whale National Marine Sanctuary
PIFSC – Pacific Islands Fisheries Science Center

APPENDIX C – Participants

Participant	*Affiliation*	*Email*
Ann Allen	NOAA Fisheries Pacific Islands Fisheries Science Center	ann.allen@noaa.gov
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Mark Deakos	Hawaiʻi Association for Marine Education & Research, HDR, Inc.	mark.deakos@hdrinc.com
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Beth Goodwin	Jupiter Foundation	beth@jupiterfoundation.org
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Meagan Jones	Whale Trust Maui	mjones@whaletrust.org
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Karen Kavanaugh	Oregon State University	
Laura Koehn	NOAA Fisheries Office of Protected Resources	laura.koehn@noaa.gov
Anke Kuegler	University of Hawai‘i	akuegler@hawaii.edu
Marc Lammers	NOAA National Ocean Service Office of National Marine Sanctuaries	marc.lammers@noaa.gov
Barbara Lagerquist	Oregon State University Marine Mammal Institute	
Ed Lyman	NOAA National Ocean Service Office of National Marine Sanctuaries	ed.lyman@noaa.gov
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Daniel Palacios	Oregon State University Marine Mammal Institute	daniel.palacios@oregonstate.edu
Susan Pultz	NOAA Fisheries Pacific Islands Regional Office	susan.pultz@noaa.gov
Angela Somma	NOAA Fisheries Office of Protected Resources	angela.somma@noaa.gov

Jan Straley	University of Alaska Southeast	jmstraley@alaska.edu
Andy Szabo	Alaska Whale Foundation	andyszabo@gmail.com
Fabien Vivier	University of Hawai'i	fvivier@hawaii.edu
Shannon Yee	National Marine Sanctuary Foundation	shannon@marinesanctuary.org

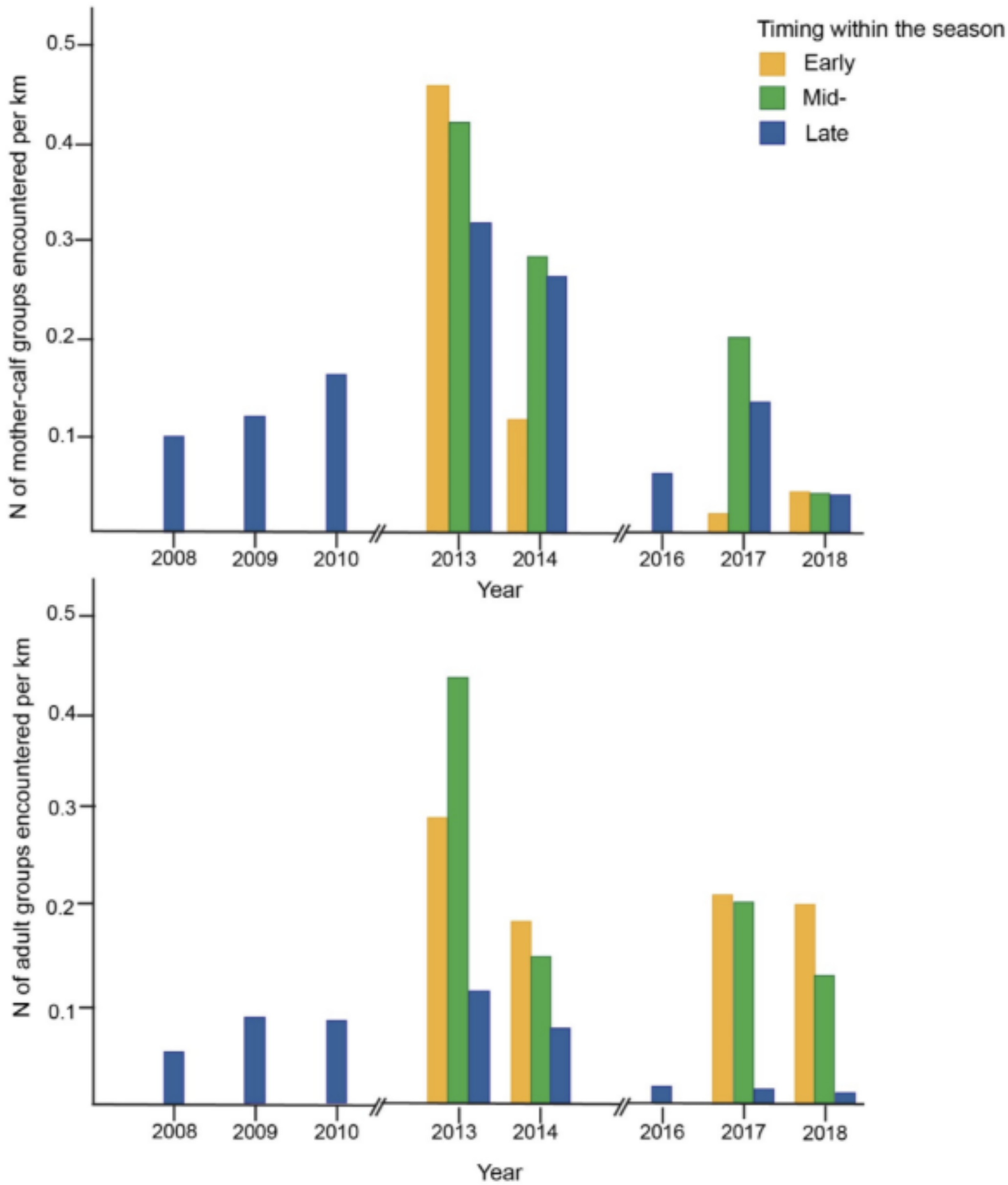
Note Takers (NOAA): Cindy Among-Serrao, Krista Graham, Kim Maison, Paul Wong

APPENDIX D - Presentations

1. **Recent declines in sighting rates of mother-calf pairs within a favored breeding region used by Hawaiʻi's Distinct Population Segment of humpback whales.**
Cartwright (1, 2), A. Venema (1), V. Hernandez (1), C. Wyels (1, 3), J. Cesere (3) and D. Cesere (3)
    1. The Keiki Kohola Project, Kihei, HI 96753
    2. California State University Channel Islands, Department of Environmental Science and Resource Management, One University Drive, Camarillo, CA 93012
    3. California State University Channel Islands, Department of Mathematics, One University Drive, Camarillo, CA 93012
    4. Cesere Brothers Fine Art Photography, Paia, HI 96779

The waters around Maui, Hawaiʻi comprise critical breeding habitat for Hawaiʻi's Distinct Population Segment of humpback whales, Megaptera novaeangliae. Between 2008 and 2018, we conducted systematic transect-based surveys in this area, recording encounter rates for different social groups of whales between the mid-channel and shoreline regions of the eastern portion of the Au'Au Channel. Traditionally, this region has comprised favored habitat for mother-calf pairs during their time in Hawaiian waters. Here, we provide details of fluctuations in encounter rates over the course of these surveys. Beginning in 2008, encounter rates increased annually, tracking projected growth rates for this population segment. Encounter rates reached a peak in 2013 and declined after this date, however the scale of this decline trends varied between different social groups. For adult-only groups, encounter rates fell by 50% between 2013 and 2014, but then remained relatively consistent at this lower level during the 2017 and 2018 seasons. In contrast, encounter rates for groups that included mother-calf pairs declined consistently between 2013 and 2018. Comparing identical surveys conducted across a two season time window in 2013-2014 vs. 2017-2018, mother-calf encounter rates dropped by 79.4%. A range of possible scenarios could account for these observations, including changes in patterns of habitat use and the possibility that this population segment may have reached carrying capacity. Additionally, recent changes in oceanographic conditions in the North Pacific may have impacted prey availability in feeding regions utilized by the Hawaiian DPS. Predictive models constructed based on the results of this study indicate that fluctuations in encounter rates for mother-calf pairs align with these recent oceanographic changes. As reproductive output is physiologically linked to nutrition in large mammals, this provides a plausible, alternate explanation for the recent changes in mother-calf numbers in Maui waters.

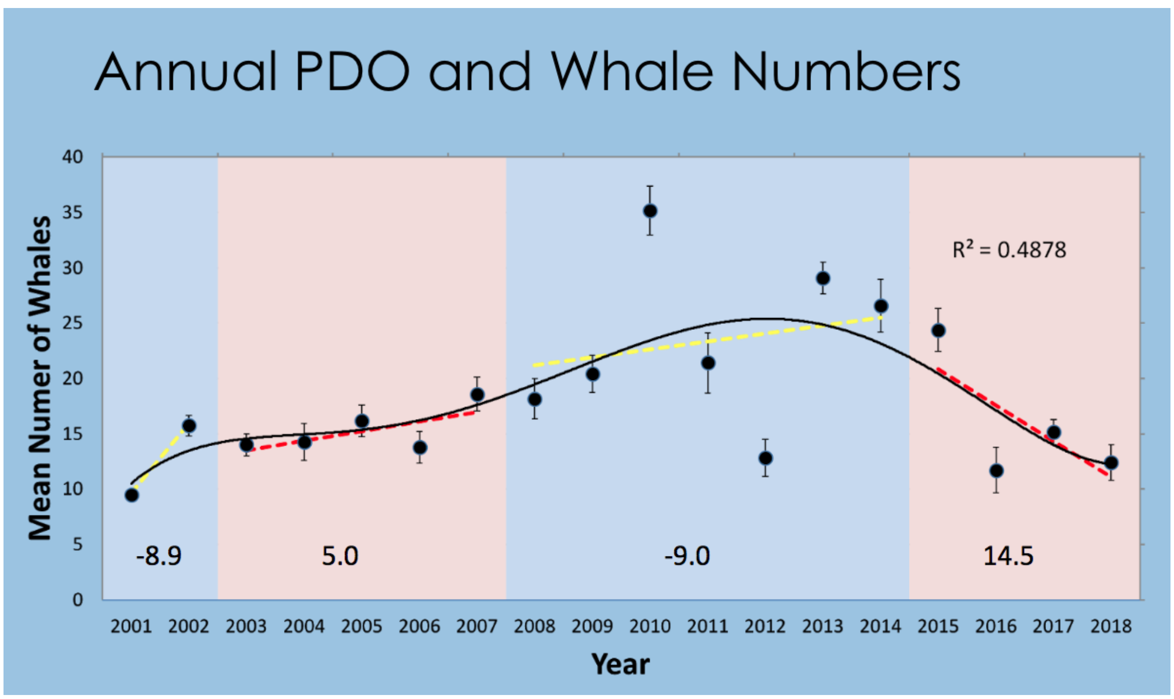
Figure 1: Encounter rates for a) mother- calf groups and b) adult groups during transect surveys of the Au'Au Channel, Maui, between 2008 and 2018



2. **Changes in Humpback Abundance 2001-2018: Climate Driven?**
Adam Frankel, Christine S. gabriele, Susan E. Yin, Susan H. Richards
Hawai'i Marine Mammal Consortium

2016 Notable Observations
- Very few whales seen
- Only three calves seen from shore; only one from boat
- Lots of "skinny" whales observed during boat surveys
- Might poor foraging be a causal factor of low whale numbers?
- Used climate indices as a proxy for forage quality

Discussion
- Most recent whale numbers are similar to those seen in 2001; calf numbers lower than in 2001.
- GAM analysis shows strong annual effect, with peak in annual trend around 2008; marked decline thereafter.
- Seasonal trend in number of whales clearly seen with peak abundance around day 45 (Feb 14).
- Better visibility predicts slightly higher whale counts.
- Strong association of cool (negative) PDO conditions with increased whale and calf numbers.



3. **Trends in humpback whales observed in Maui Nui between 2012-2018.**
Jens Currie, Stephanie Stack
Pacific Whale Foundation, Maui, HI, USA

Pacific Whale Foundation recorded humpback whales in the leeward waters of Maui County from 2013-2016 using systematic line transect surveys. The pod size, age-class, and position of each whale that came within 300 meters of our research vessel was recorded. We examined the number of total whales and the number of adults, sub-adults, and calves to identify trends in the number of whales present in Maui waters during humpback whale breeding and calving season. We found the total number of whales decreased 54.6% from the 2012-2013 season to the 2015-2016 season with the largest decrease observed in the adult age-class, which had a 75.6% decrease.

We additionally examined our photo-identification data collected during the same time period; photographs and associated data were collected opportunistically aboard whale watching trips departing from both Maalaea and Lahaina Harbors, Maui. The number of individual whales cataloged each year did not vary significantly, however, the distance traveled by the whale watching vessels has risen during this time period. To watch the same number of whales, vessels doubled their search effort in the 2015-16 season compared to the year prior.

Data collected during the Great Whale Count, a citizen science count of humpback whales visible 3 miles from shore, shows a pattern of decreasing whale sightings. The number of whales counted during this event has sharply declined from 2015 to 2018 with a 64.5 % decrease in the number of whales and a 37.4% decrease in the number of calves.

Pacific Whale Foundation has partnered with the Marine Mammal Research Program at University of Hawai'i - Manoa to investigate the energetics of the Hawai'i-Alaska migration and how this could be affecting whale health.

Changes in the number of humpback whales in Maui Nui waters from 2013-2018 as determined from systematic surveys and citizen science monitoring.

Line transect data 2013-2016:

	Average Yearly Change	Overall Change
Number of Whales (all ages)	-22.6 %	-54.6 %
Number of Adults	-36.2 %	-75.6 %
Number of Sub-adults	8.6 %	-4.2 %
Number of Calves	-25.8 %	-60.6 %

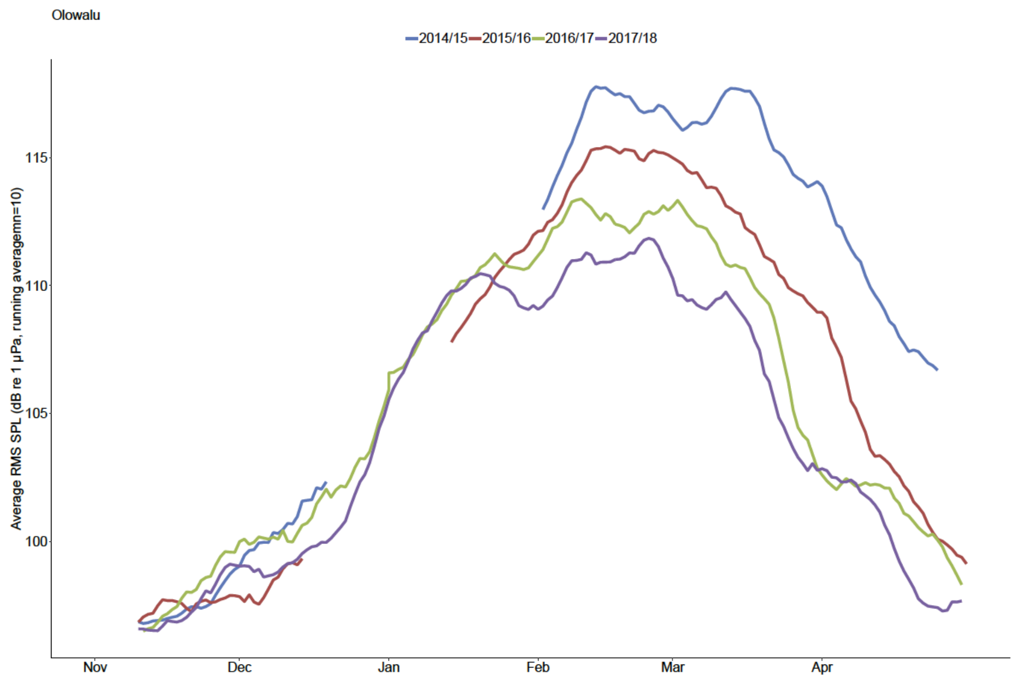
Great Whale Count data 2015-2018:

	Average Yearly Change	Overall Change
Number of Pods	-23.2 %	-62.7 %
Number of Whales (all ages)	-20.9 %	-64.5 %
Number of Calves	-13.2 %	-37.4 %

4. **Trends in male humpback whale song chorusing off Maui, Hawai'i since 2014/2015**

Anke Kügler (1,3), Marc Lammers (1,2), Eden Zang (3), Max Kaplan (4), Aran Mooney (4)
1. University of Hawai'i at Manoa, Honolulu, Hawai'i
2. Hawai'ian Islands Humpback Whales National Marine Sanctuary
3. Oceanwide Science Institute, Makawao, Hawai'i
4. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

Each winter, thousands of humpback whales *(Megaptera novaeangliae)* migrate from their high latitude feeding grounds in Alaska to mate and calve in the shallow tropical waters around the Main Hawaiian Islands. Population estimates suggest that up to 12,000 animals winter in Hawaiian waters, making up more than half of the total North Pacific stock. At the breeding ground, all mature males produce an elaborate acoustic display known as song, which becomes the dominant ambient noise during the season from December through April. In the 2015/2016 season, anecdotal reports from commercial operators and researchers as well as citizen-science whale counts tell of an unusually low number of whales compared to previous years off the island of Maui. Hawai'i. Data from long-term passive acoustic monitoring with autonomous bottom-moored Ecological Acoustic Recorders (EARs) during the 2014/2015, 2015/2016, 2016/2017, and 2016/2017 seasons at three shallow-water and two deep-water sites within the Maui Nui area were analyzed using male chorusing levels as a proxy for relative whale abundance. Root-mean-square sound pressure levels (RMS SPLs) were calculated to compare low frequency acoustic energy (0-1.5 kHz) among all seasons. Our results showed that despite a similar onset of the season and similar overall trend reflecting the migratory pattern of humpback whales, on average per month SPLs remained up to more than 6dB lower since 2014/15 on all sites, suggesting that the number of singing males was indeed lower during all subsequent years in Maui Nui and whales did not seem to have shifted to deeper waters within the area. Further, peak chorusing levels shifted, suggesting that whales leave the region earlier than in the past. It remains unclear whether our observations reflect a decrease in population size or a behavioral response and continued and expended monitoring effort, including previously surveyed areas, is warranted.



5. **Hawaiian Islands Humpback Whale National Marine Sanctuary monitoring: Some Associated Trends**
   Edward Lyman, Rachel Finn and Marc Lammers
   Hawaiian Islands Humpback Whale National Marine Sanctuary

   Since 2002, Hawaiian Islands Humpback Whale National Marine Sanctuary has partnered with the on-water community to monitor the health of, and risks to, humpback whales around the main Hawaiian Islands. The sanctuary also performs dedicated monitoring, primarily in leeward Maui, using standardized methodologies including photo ID, and visual health and risk assessment through surface, aerial, and in-water means. Between 2002 and 2014, ship-strike and entanglement reports generally increased. Beginning in 2014 ship-strike reports generally began decreasing, followed by entanglement reports in 2016. Temporal variation existed in both, with the number of confirmed entanglement reports aligning somewhat with environmental factors such as El Niño and the Pacific Decadal Oscillation. Entanglement scar rates have remained consistent over time. Recently more reports have involved entanglements in nearshore gear (e.g. mooring). Health analysis did not indicate especially emaciated animals, though more quantification is needed. Opportunistic vessel-based transects performed since February 2016 within the ʻAuʻau Channel, Maui, indicated a 38% relative decrease in sightings between 2016 and 2017 season ends, and a 16% decrease between 2017 and 2018 seasons. Over 1000 animals have been photo-identified, representing a substantial contribution towards shared population monitoring. Demographic analysis showed trends, like a decrease in the number of competitive groups encountered and in their size since 2012, perhaps corresponding to a decrease in breeding behavior or in the number of animals. Surprisingly, an increase in calves was encountered, possibly representing movement further offshore and into the sample area. The Sanctuary's Ocean Count, a monthly shore-based citizen science survey conducted during peak whale months off the islands of Kauai, Oahu, and Hawai'i since 1996, provided a long-term dataset on relative sightings. An analysis comparing sightings for the three seasons prior to and after 2016 off Kauai, showed a 37.3% decrease in sightings. Risk factors like entanglement may represent small datasets, but combined with sighting rates, demographics, health assessment, and/or long-term photo ID, may complement other datasets, increasing our understanding of changes that might be occurring in the population and their causal factors.

Figure 1: 2017 transect results from southeastern Auau Channel, Maui

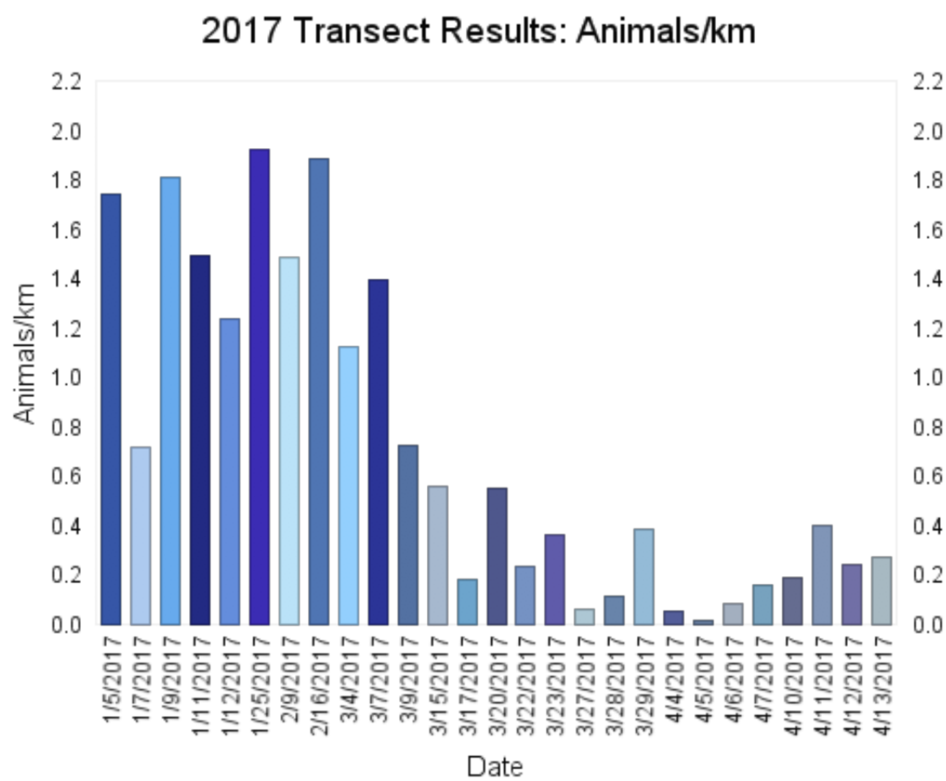
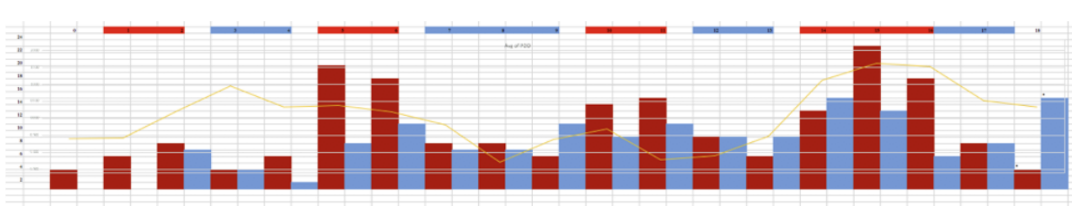


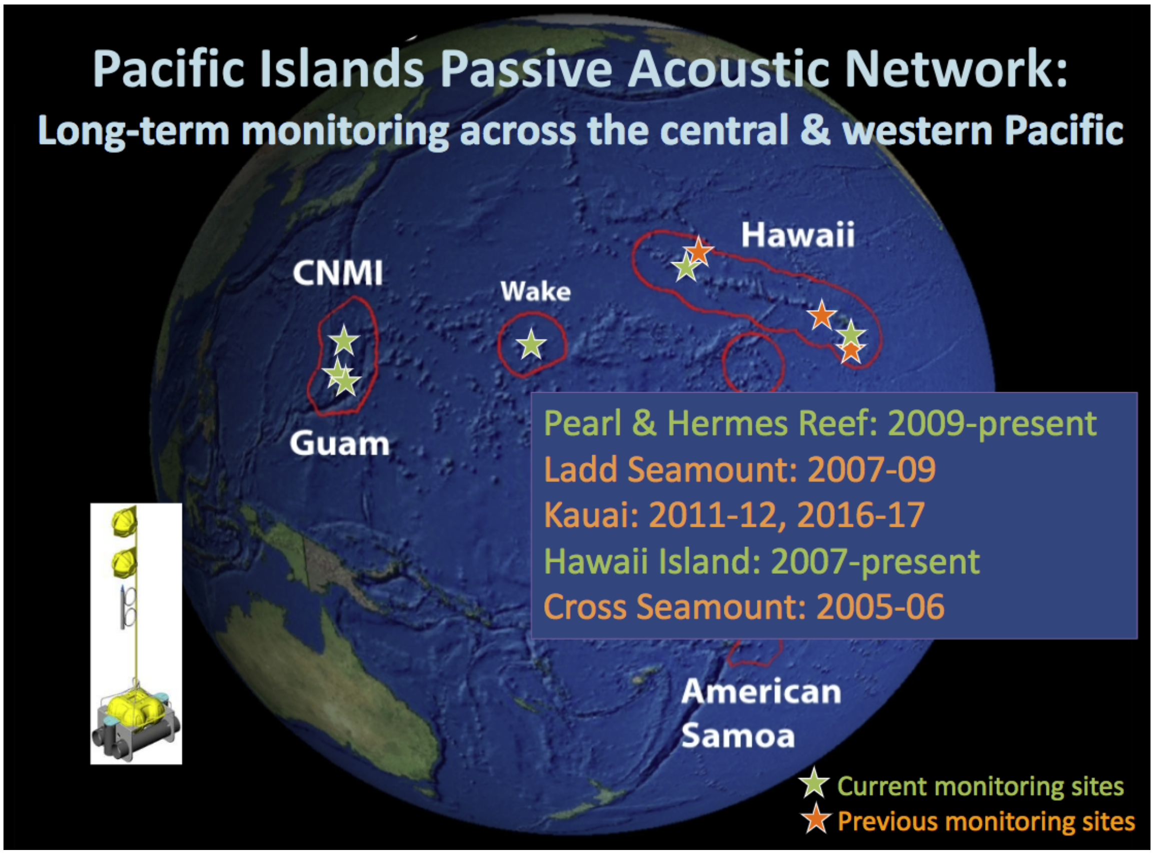
Figure 2: Confirmed humpback whale entanglement reports from Alaska and Hawaii overlaid with environmental data (El Nino, La Nina, and Pacific Decadal oscillation cycle)



* *Upper horizontal red and blue bars represent El Nino and La Nina cycles*
Yellow line represents PDO index
Vertical red and blue bars represent AK and HI confirmed entanglement reports

6. Winter HICEAS 2019 and contributions of the PIPAN dataset to examining humpback whale trends

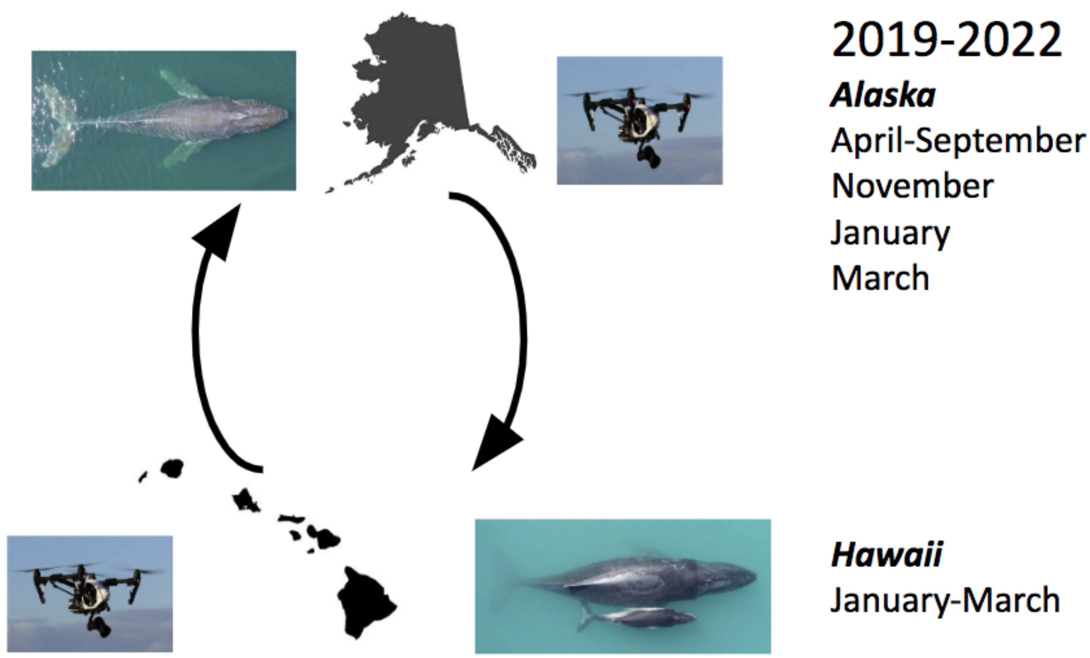
Erin Oleson and Ann Allen
Cetacean Research Program
NOAA Fisheries, Pacific Islands Fisheries Science Center



7. **Developing a bioenergetic model for humpback whales by assessing their body condition across their Alaskan feeding grounds and Hawaiian breeding grounds**
Lars Bejder, Hawai'i Institute of Marine Biology
Andy Szabo, Alaska Whale Foundation

Developing a bioenergetic model for humpback whales by assessing their body condition across their Alaskan feeding grounds and Hawaiian breeding grounds by:

1. Quantify change in body condition across foraging and breeding grounds.
2. Explore links to large-scale oceanographic features, e.g. Pacific Decadal Oscillation, El Nino.
3. Compare body condition to other humpback whale populations.



8. Movements and Habitat Use of Humpback Whales Satellite-tagged in Hawai'i (1995-2018)

Bruce R. Mate, Daniel M. Palacios, Tomas Follett, Craig E. Hayslip, Ladd M. Irvine, Barbara A. Lagerquist, Martha H. Winsor
Marine Mammal Institute and Department of Fisheries and Wildlife, Oregon State University, Newport, OR, USA

Oregon State University has conducted satellite tagging on humpback whales *(Megaptera novaeangliae)* at several locations in the North Pacific Ocean over the period 1995–2018. In this presentation we provide an overview of these tagging efforts with an emphasis on the Hawaiian Islands. Of 100 tags deployed during this period, 81 transmitted for 1-178 days, revealing the complexity of migratory destinations from Hawai'i, including complete migrations to Southeast Alaska, the Aleutian Islands, and the Kamchatka Peninsula off Russia, including extensive use of a seamount and a subsequent change of direction from the presumed destination. They also revealed a high degree of movements within the Main Hawaiian Islands, extensive use of both leeward and windward sides of the islands, and the departure points at the initiation of migration. On average, whales spent 12 days from tagging to departure (range: 1-43 days). In terms of habitat use, seafloor depth was on average 136 m for whales tagged off Maui, 115 m for whales tagged of Hawai'i, and 334 m for whales tagged off Kauai. The aggregate distribution of tag locations indicated density "hotspots" within the Maui Nui region extending to the Penguin Bank).

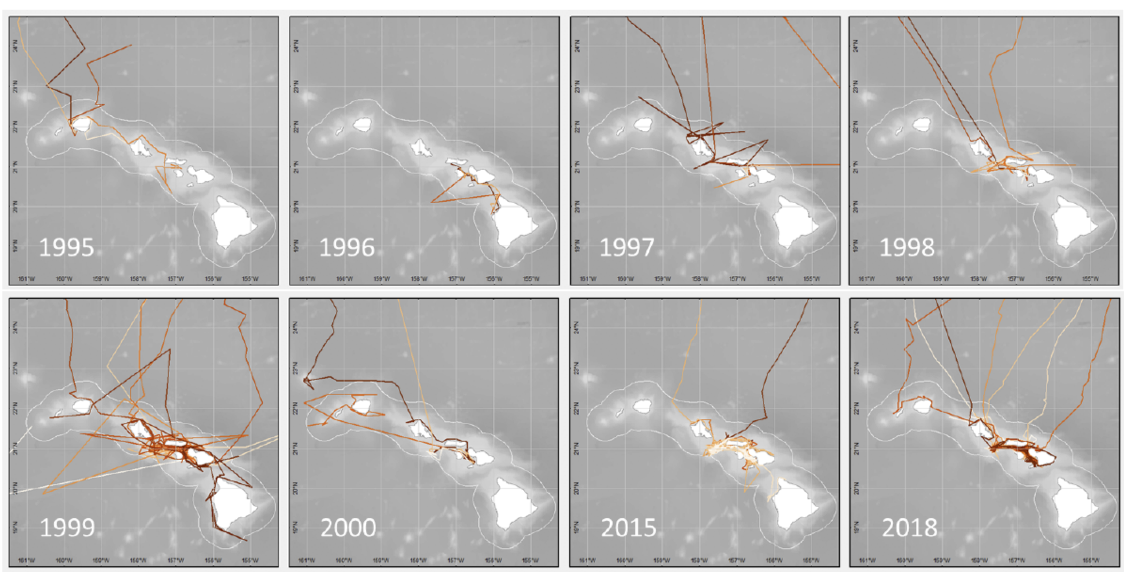
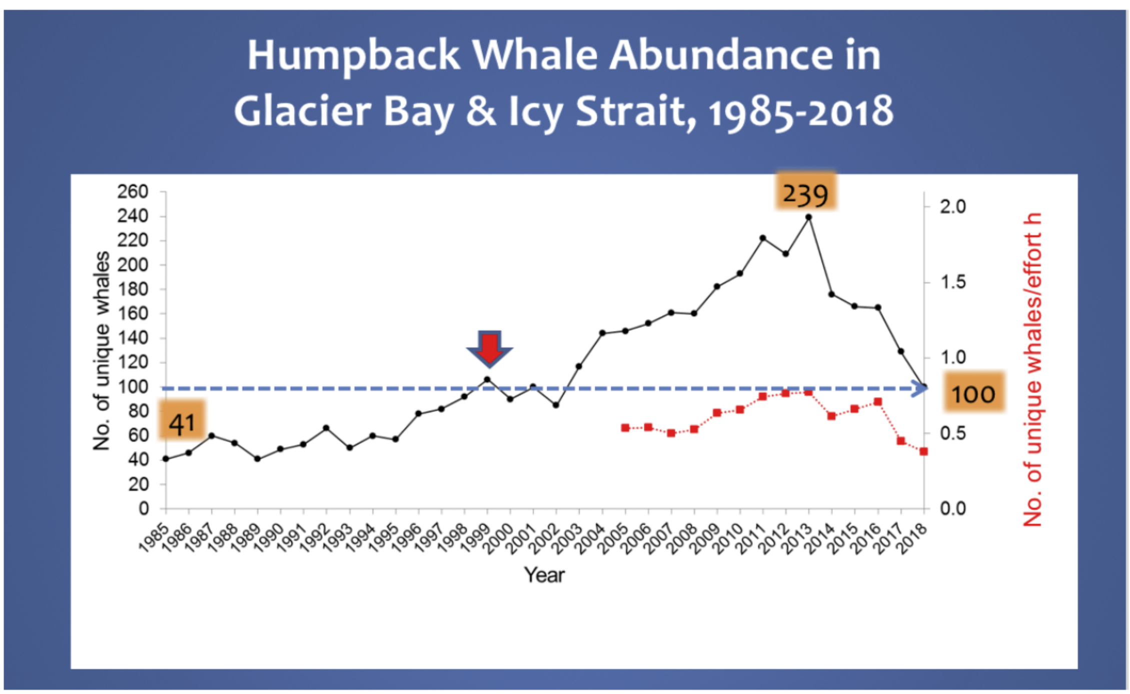


Figure 1. Satellite-tracked movements of humpback whales tagged with Argos-monitored radio tags deployed by Oregon State University in the Hawaiian Islands in eight years over the period 1995-2018.

9. Recent Population Level Changes in Glacier Bay and Icy Strait Humpback Whales

Christine M. Gabriele and Janet L. Neilson
Glacier Bay National Park and Preserve

From 1985-2018, the Glacier Bay National Park humpback whale monitoring program used consistent methods and levels of effort to monitor individually-identified humpback whales annually from June 1 to August 31 in Glacier Bay and Icy Strait. We photographically identified and counted the number of different whales and documented how many were calves of the year. We calculated the crude birth rate (CBR) as an annual reproductive index by dividing the number of calves by the total whale count for each year. After many years of considerable reproductive success, we documented a sudden, sharp decline in humpback whale numbers, productivity and juvenile survival beginning in 2014. Total whale abundance in 2018 (100 whales) declined for the fifth year in a row and we only observed one cow/calf pair. Additionally, the only female documented to produce a calf in 2018 (#1470) lost her calf by early August, adding to a trend of low calf and juvenile survival that began in 2014. The CBR over the past five years (2014-2018 mean = 2.8%) is significantly lower than typical CBRs prior to 2014 (1985-2013 mean = 9.3%). Site fidelity of individual whales, some of which have sighting histories in excess of 30 years, has declined substantially. Methods to systematically characterize body condition indicate a varying proportion of whales that exhibit signs of emaciation and poor health. Low numbers of whales and very few calves have been documented elsewhere in Southeast Alaska in the SPLISH program since at least 2016, indicating that these declines are not unique to the Glacier Bay – Icy Strait area.



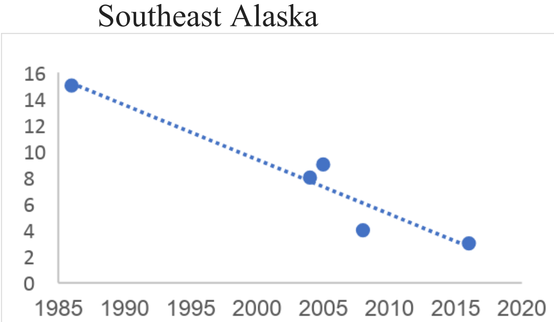
10. Ecosystem implications for the decline in reproductive success in humpback whales in the Gulf of Alaska

Jan Straley, John Moran, Chris Gabriele, Janet Neilson, Scott Baker

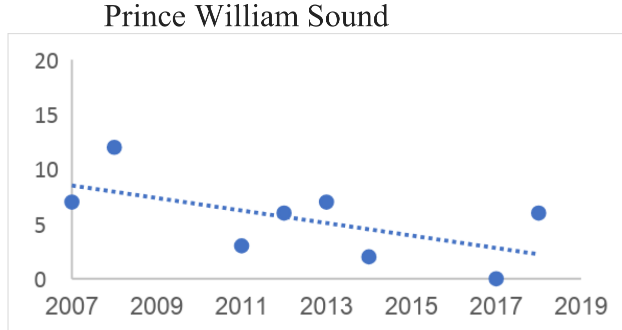
Since the marine heat wave in the North Pacific (2014-2016), humpback whales from two feeding areas in the Gulf of Alaska have returned from their winter breeding ground in Hawaiʻi with fewer calves when compared to the previous decade(s). In central Southeast Alaska, the same areas were surveyed (Frederick Sound, Stephens Passage, and Chatham Strait) between 15 July to 15 August across 4 decades. The percentage of calves (number of calves/total # of whales identified) seen in 1986, 2004, 2005, 2008 ranged from 15% to 8% and in 2016 was 3%. In Prince William Sound, the same route was surveyed during September to December during 7 years across an 11-year time span, 2007 to 2018. The percentage of calves was highest in 2008 at 12%, then dropped to less than 3% in the later surveyed years. In 2017, no calves were seen and a 90% decline in the number of whales was documented relative to the average number of whales identified in the previous 6 surveys. Declines in calving rates could be an indicator of oceanographic changes resulting in a major shift in the forage base for these predators. Reduced prey availability may necessitate these whales spending more time foraging to meet the energetic demands needed for reproduction. These energetic demands could be met by increasing time on the feeding grounds or skipping a migration altogether. In both of these areas Pacific herring are the preferred prey of humpback whales during the winter months. An increase in the number of whales present during the winter will result in increased pressure on recovering herring populations when whale predation is typically at a minimum. Alternatively, if the Gulf of Alaska fails to recover from the recent ecosystem changes due to a 2014-2016 warming event and the abundance of forage species remains low, the humpback whale population may readjust to a smaller population.

Percentage of calves seen each year

Southeast Alaska



Prince William Sound



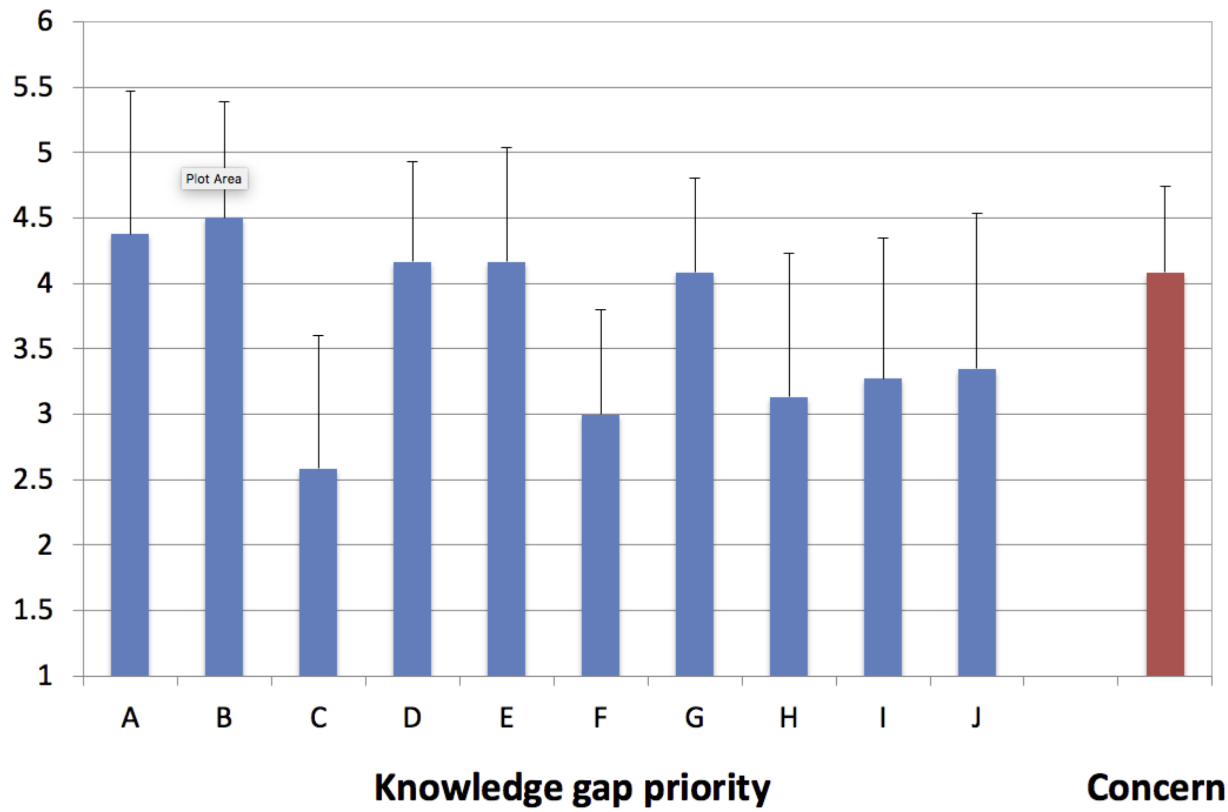
APPENDIX E - Hypotheses Notes

Table 1. Potential hypotheses to explain observed trends

Hypothesis	Questions
Nutritional Stress	
Lack of prey quantity and quality (lipid content). Ocean acidification affecting plankton. Climate change/ocean warming. Prey advection (movement/relocation). Prey recruitment. Prey availability- movement, e.g. depth, offshore, etc. Competition w/ other species. Competition w/ fisheries.	Are they changing their prey (Is there any fisheries data to support this?) Relocation -- Are humpback whales moving to different areas to find food? Reproductive analysis. Demographic data. Morphometrics. Are the size and shape of humpback whales changing? Is there a population level disturbance? Redo parts of SPLASH to get further answers. Are environmental indicators changing?
Change in Distribution	(examples of other species)
Independent of nutritional stress. Caused by nutritional stress. Moved to different areas: • Not finishing migration • Northwestern Hawaiian Islands • Mexico • Less time in main Hawaiian Islands • Alaska • British Columbia Not a population-level problem?	Need more data to support or refute. More effort into photo ID records. Sharing of separate photo ID databases to see if animals have moved. Environmental indicators. Exploration of other potential breeding sites. Look at temporal factors. Remote sensing. Acoustic recordings in NWHI, Wake, and Bering Sea (look at data collected and continue collecting). Look at historical changes in water temp. and salinity in Hawaiʻi & seamounts. Additional tagging in the foraging and breeding grounds to look for distributions we do not presently recognize. Ocean noise needs to be analyzed. Hindcasting models on humpback habitat to ID needs so we can see what distribution looks like now. Is there now more suitable habitat at Kure and Lisianski vs. years past?

Hypothesis	**Questions**
Change in Distribution	*(continued)*
	Are they gathering at seamounts now, and if so, why (changing food strategy or desperate)? Check fecal samples to see if diet has changed What's happening offshore?
Pathogens	
Heavy metals & plastic HABs PCBs & other man-made chemicals	Trace elements analysis. Proportion of bumpy whales - 80% of Hawai'i whales have bumps. Unknown cause, need more information. Look at pathogens that impact reproductive system. All humpback whales need full necropsy including biopsies Need to look further at anthropogenic chemicals.

APPENDIX F - Ranking of Knowledge Gaps



A. Population health - 2nd
B. Distribution of whales - 1st
C. Interactions among the various populations - 10th
D. Demographic trends - 3rd
E. Prey distribution and quality - 3rd
F. Anthropogenic risk factors - 9th
G. Environmental drivers - 5th
H. Ecosystem health - 8th
I. New prey base - 7th
J. Compare Hawaiʻi distinct population segment to other populations - 6th

APPENDIX G - Survey used in workshop

Trends in humpback whales meeting
RANKINGS

NAME ____SAMPLE ONLY______________________________

A. Based on the evidence presented at this meeting and the ensuing discussions, please indicate your level of concern about the reported trends in the Hawai'i/Alaska humpback whale population (circle one).

1	2	3	4	5
Not concerned		Somewhat concerned		Very concerned

B. Several potential or ongoing research efforts have been proposed to address the current knowledge gaps limiting understanding of the observed trends. Please indicate your assessment of the priority level associated with each effort based on need, logistic feasibility, cost, etc. Circle one priority level for each research effort listed.

Effort	Low priority		Medium priority		High priority
A.	1	2	3	4	5
B.	1	2	3	4	5
C.	1	2	3	4	5
D.	1	2	3	4	5
E.	1	2	3	4	5
F.	1	2	3	4	5
G.	1	2	3	4	5
H.	1	2	3	4	5
I.	1	2	3	4	5
J.	1	2	3	4	5

APPENDIX H - Original version of Knowledge gaps (not prioritized)

	Knowledge gaps	Means of addressing / type of research
A.	Development of a health assessment protocol	Collection of samples for biomarker analysis (e.g. stomach content, blubber, reproductive tracts, respiratory vapor, stress hormones), morphometrics (linking photos to UAV measurements to compare with historic data and increase avail data), historical stranding data,
B.	Where are they? Where do they go to breed and feed? Are they offshore / how much are they using seamounts? Where are Southeast Alaska and Prince William Sound whales? Where are Hawai‘i whales?	Tagging, photo-ID, acoustics, remote sensing (wave gliders, satellite tags, fixed-wing UAVs, aerial surveys, etc.), platform of opportunity for data collection Compare catalogs Aerial surveys (density, redistribution; in NWHI, Cross Seamount and other close seamounts)
C.	Interactions between the various populations	Satellite tags, photo-IDs, song characteristics, genetics, meta analysis from other populations, population modeling to explore questions to ask
D.	Population parameters: age structure, numbers, productivity, reproductive patterns, vital rates	Leveraging existing catalogs (Happy Whale), age structure with UAVs, pregnancy rates w/ blubber biopsies, calving intervals w/ database, reproducing a mini-SPLASH to focus on local/regional studies, aerial surveys, reproductive hormones, calf mortality rates
E.	Change in prey availability and distribution. How does it relate to fisheries quantity and quality ?	Shift in diet using stable isotopes, fisheries catch data, chlorophyll levels, hydro acoustic surveys, net trawl surveys, modeling of prey, comparative analyses, prey composition analysis
F.	Anthropogenic risk factors: vessel collisions, noise, tourism, plastics, pollution, oil spills, entanglement, habitat degradation (development/construction)	Entanglement rates, necropsy records, scar analysis, behavioral analysis (tourism effects), underwater sound monitoring, toxicology, AIS monitoring, measurement of microplastics in whales, necropsies, stomach content analysis, risk factor that encompasses all these risks, encounter model, ear wax plugs

	Knowledge gaps	Means of addressing / type of research
G.	Environmental drivers: chlorophyll, salinity, sea surface temperature, carbon dioxide, oceanographic events (e.g. Pacific Decadal Oscillation), acidification	Meta analysis and modeling as they relate to observed trends (hypothesis-driven at the appropriate scale), combine different data sources to augment predictive power
H.	Ecosystem health (e.g., domoic acid, saxitoxins), trophic cascade	Monitored through the food chain (e.g., crustaceans), coordinate with public health researchers (e.g. harmful algal bloom lab in Sitka),
I.	Are they using new and/or different prey?	Stable isotopes (e.g. fecal, blubber, baleen) analysis, SPLASH data (as comparison), workshop to leverage info from fishermen, etc. (need to give them cameras for proof; get buy-in from them)
J.	Compare Hawai'i DPS with what is happening in other North Pacific populations	Consultation with humpback whale experts from other DPS(s)

Last page of report.