1. Project Number:

20120114-O

2. Project Title:

Long-term Monitoring of Humpback Whale Predation on Pacific Herring in Prince William Sound

3. Principal Investigator(s) Names:

John Moran, NOAA Fisheries AFSC/Auke Bay Laboratories

Jan Straley, University of Alaska Southeast

4. Time Period Covered by the Report:

February 1, 2020-January 31, 2021

5. Date of Report:

March 2021

6. Project Website (if applicable):

www.gulfwatchalaska.org

7. Summary of Work Performed:

The objectives of the long-term monitoring of humpback whale predation on herring in Prince William Sound (PWS) project include the following:

1. Estimating trends in humpback whale abundance, diet, and distribution
2. Evaluating prey quality and trophic position through chemical analysis (using bomb calorimetry and stable isotopes)
3. Estimating the impact of humpback whale predation on herring

Humpback whale survey work in 2020 was compromised by the COVID-19 pandemic. Federal and state health mandates were put into place as planning for the spring survey was ongoing. Thus, we were unable to conduct a spring survey due to travel restrictions. However, we did receive updates on humpback whale abundance and distribution during the herring spawn from the Herring Research and Monitoring (HRM) program team, Alaska Department of Fish and Game (ADF&G), and citizen scientists. The humpback whale portions of the fall Integrated Marine Predator-Prey (IMPP) was completed without the benefit of the forage fish team and marine bird observer due to COVID-19 restrictions. This limited our ability to identify and capture prey. In addition to disruptions of fieldwork, there were also delays in the chemical analysis of prey samples.

Trends in humpback whale abundance, diet, and distribution

We completed the humpback whale component of the IMPP survey in September without the fall/winter marine bird (20120114-E) and forage fish (20120114-C) projects. Although we did not conduct the spring humpback whale survey, based on anecdotal reports, no recovery in whale numbers occurred during the herring spawn. Fall whale numbers declined again in 2020 after a slight increase in 2019 (Fig. 1).

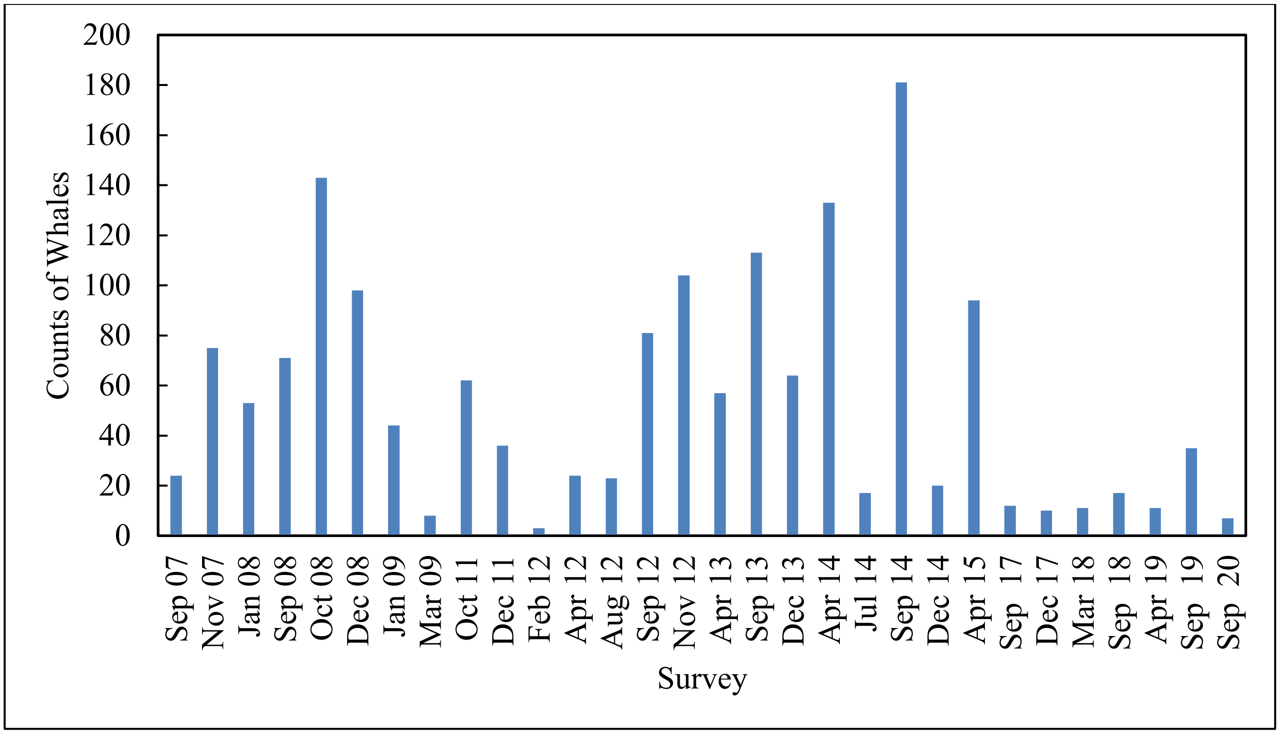

Figure 1. Counts of humpback whales during Exxon Valdez Oil Spill Trustee Council and National Oceanic and Atmospheric Administration funded surveys in Prince William Sound.

Humpback whale numbers have failed to rebound in Prince William Sound (PWS) following a decline associated with the 2014-2016 marine heatwave in the Gulf of Alaska. Encounter rates for humpback whales during the 2020 fall survey were lower than the preceding years (Table 1). The reduction of humpback whales possible related to a decline in the biomass of herring in PWS or lingering population effects from the marine heatwave. Fall surveys are consistent in the area searched that allows for comparisons between years to establish trends. Spring and winter surveys tend to have more variation in duration. These surveys allow us to capture seasonal variation in humpback whale numbers.

*Table 1. Encounter rates of humpback whales in Prince William Sound during fall surveys. * The 2007 survey did not cover Montague Entrance, an area known for the highest concentration of whales and herring during early fall. Gulf Watch Alaska sampling began in 2012, no surveys were conducted in 2015-16, but resumed in 2017 and will continue annually as funding allows.*

Month/year	Counts of whales	Nautical miles surveyed	Encounter rate Whale/NM
Sep 2007*	24	370	0.06
Sep 2008	71	412	0.17
Oct 2011	62	441	0.14
Sep 2012	81	444	0.18
Sep 2013	113	355	0.32
Sep 2014	181	427	0.42
Sep 2017	12	543	0.02
Sep 2018	17	541	0.03
Sep 2019	32	527	0.06
Sep 2020	7	337	0.02

Most humpback whales that feed seasonally in the Gulf of Alaska migrate to Hawaii or Mexico for mating and calving. Successful reproduction in humpback whales requires three years of adequate foraging. After the first year, the female must have enough reserves to migrate to the breeding grounds, ovulate and conceive. Gestation takes place over the next year. This involves a fasting migration to and from the feeding grounds. Finally, after parturition, there must be enough prey available upon returning to the feeding grounds to support lactation and weaning the calf. Two humpback whale calves were seen during the six survey days in the fall of 2020 (Fig. 2). This may reflect the dramatic increase in calves seen in Hawaii and Southeast Alaska during 2020. High calf numbers in other regions of the Gulf of Alaska suggest a sufficient prey base for whales from 2018 to 2020, however, given the low overall whale numbers in PWS it is difficult to make assumptions about prey abundance and quality within the Sound. In PWS, the decline in numbers of whales and calves seen in the fall pre- and post-marine heatwave was significant (Figs. 1 and 2). In 2008, a high of 140 unique whales and 17 calves was documented. Only three calves were seen during our surveys from 2015 to 2020. The discovery curve of individual whales in PWS remains flat into 2020 the result of no new whales and lower calf production (Fig. 3).

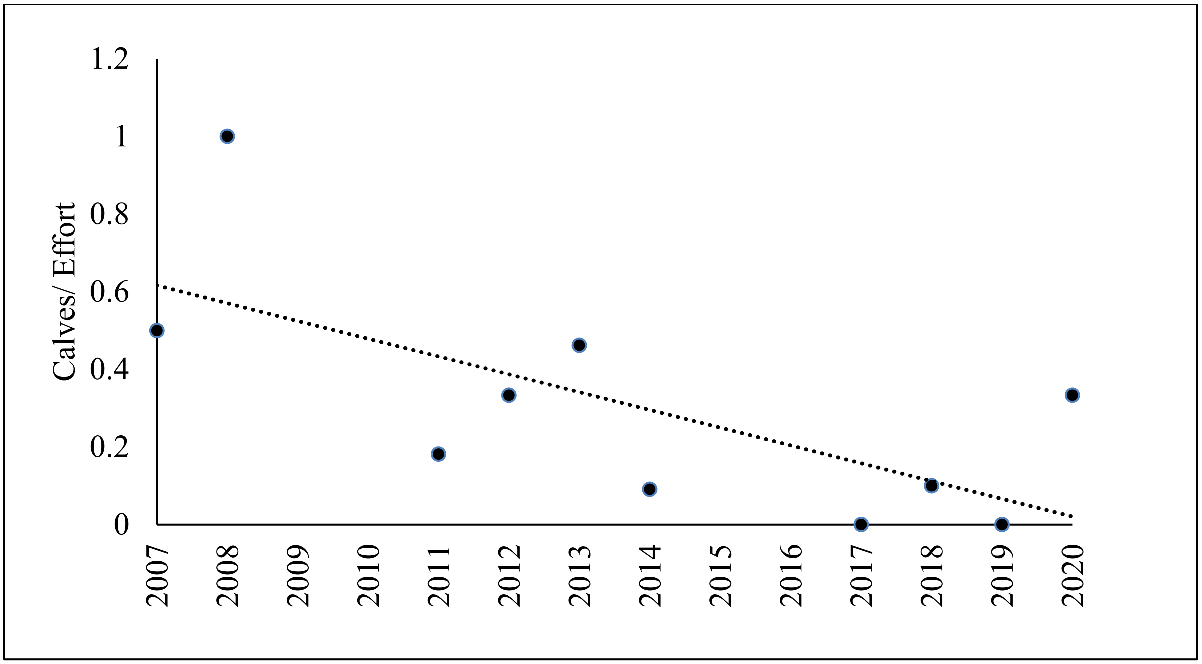

Figure 2. The number of humpback whale calves seen /survey day in Prince William Sound.

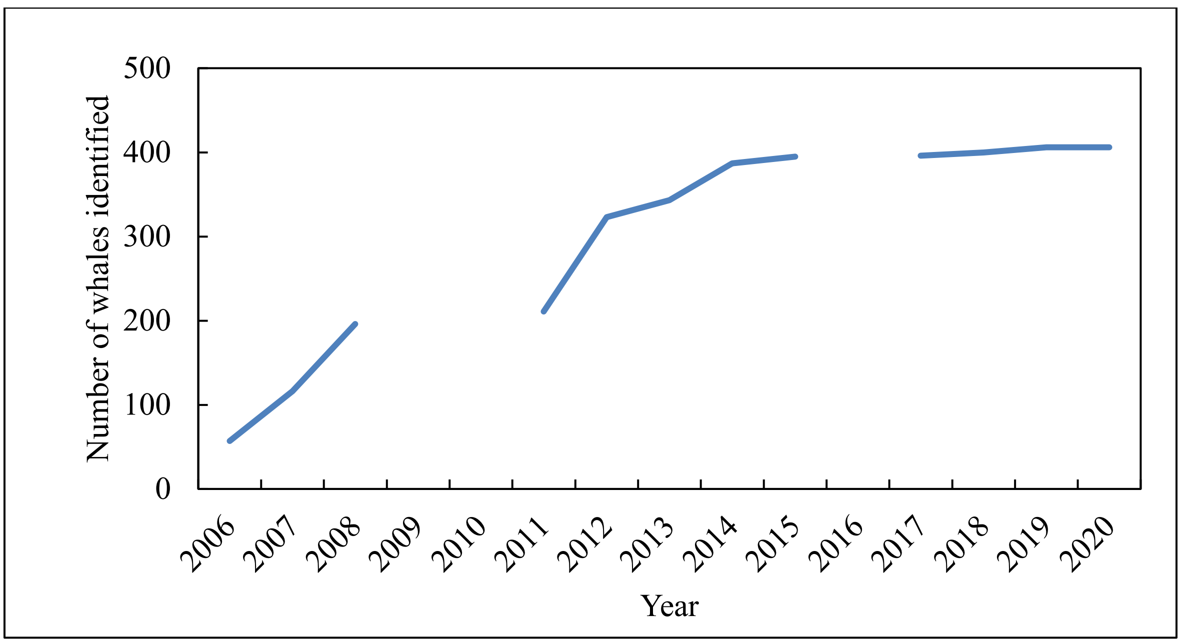

Figure 3. Discovery curve for humpback whales in Prince William Sound. The curve flattens in 2014, the result of reduced immigration and lower calf production (calves are not included).

The fate of the missing whales remains unknown. We have joined a collaborative research effort across the North Pacific Basin that was initiated in winter of 2019 by Happywhale (happywhale.com) and the North Pacific Humpback Whale Photo ID Study Group (North Pacific Group). Multiple research groups are contributing their catalogs of whale flukes to Happywhale to increase the understanding of movements of humpback whales across the North Pacific. Happywhale compared images of ~400 whales in the PWS catalog by using automated image recognition, with images managed within the Happywhale system. This system provides rapid automated comparisons of, at present, photos of more than 24,000 individual humpbacks, thus greatly reducing the time required from labor-intensive manual matching. The catalogs (some incomplete) that have been compared to date are from Russia, Hawaii, Mexico, California, Oregon, Washington, British Columbia, Southeast Alaska, summer PWS, Gulf of Alaska, Kodiak, and Alaska Peninsula. Happywhale matching will be ongoing as catalogs are completed and updated and new catalogs are submitted. Preliminary new findings have found strong connections to the Kodiak area and more PWS/Southeast Alaska connections than previously known (Fig. 4). In time, missing whales should show up on the breeding grounds or in other feeding areas if they are still alive.

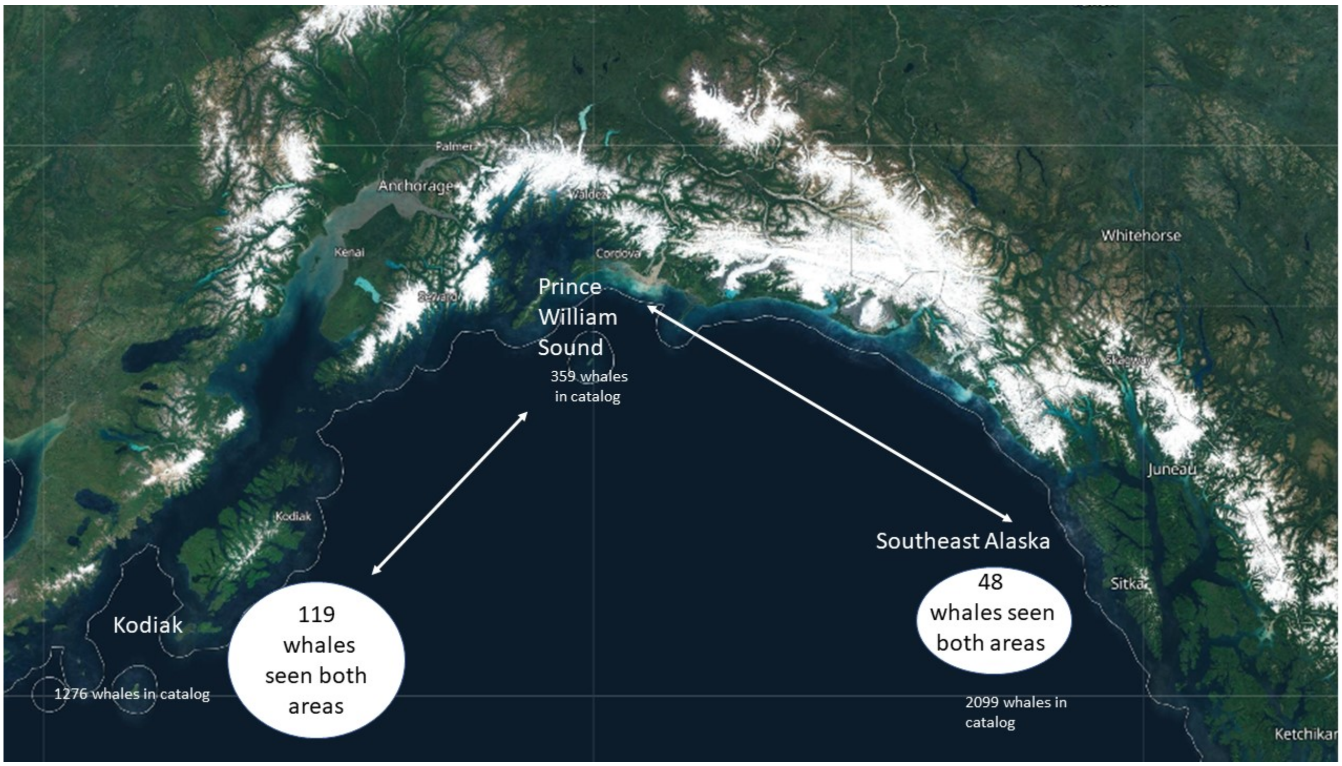

Figure 4. The Prince William Catalog from our Gulf Watch Alaska study was matched to other catalos in the Gulf of Alaska. Kodiak data were collected until 2015 and Southeast Alaska from 1979 to 2021. The Prince William Sound data included photographs contributed by Gulf Watch Alaska partner North Gulf Oceanic Society.

Prey quality and trophic position through chemical analysis (using bomb calorimetry and stable isotopes)

We continued to monitor trophic level and energy density for forage species in PWS. Because of COVID-19 health mandates and travel restrictions, the fall whale survey proceeded without the forage fish and marine bird components of the IMPP. This made it difficult to sample prey and only a few herring were collected. Due to the small number of whales seen during the survey, we could not determine the preferred forage species. In previous years following the marine heatwave, we saw whales targeting small schools of juvenile herring, usually less than 0.5 m in diameter, low quality prey that may incur higher foraging cost when compared to large shoals of adult herring (Fig. 5). Our analysis of these fish detected an increase in energy density, suggesting that they may be improving in body condition (Fig. 6).

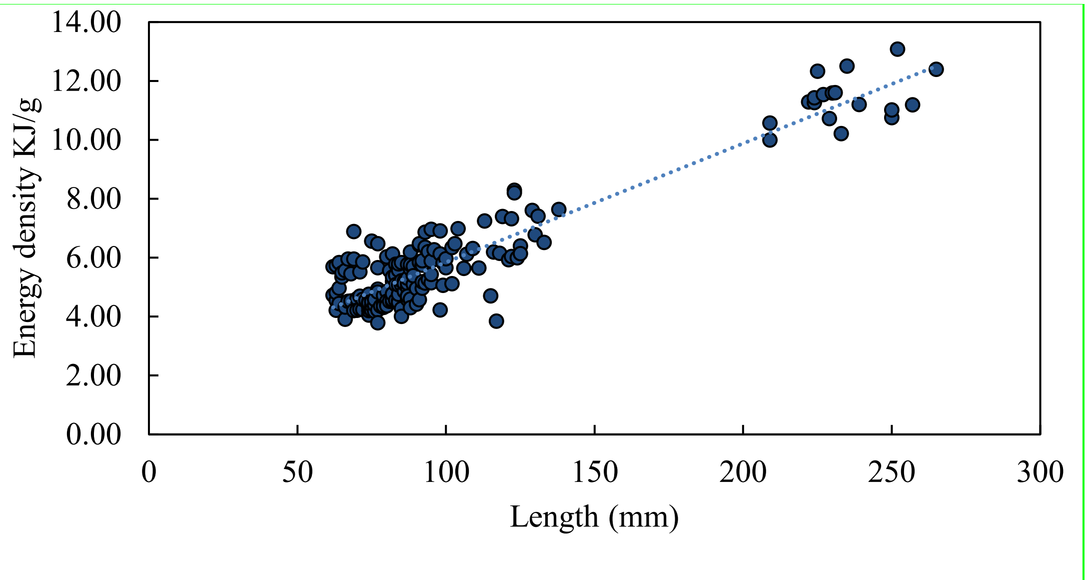

Figure 5. Energy density (kJ/g) of Pacific herring by length collected in Prince William Sound.

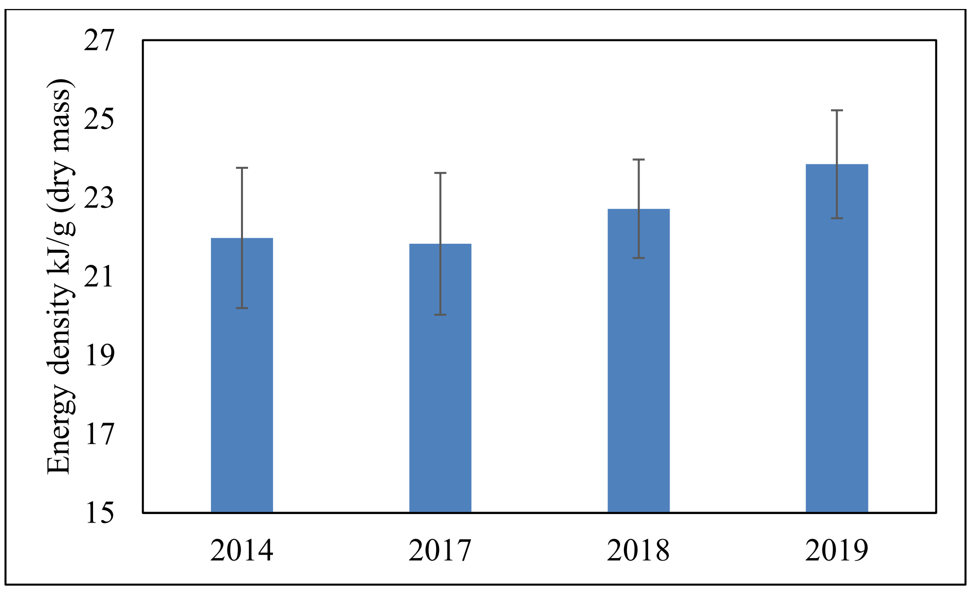

Figure 6. Changes in energy density of juvenile Pacific herring collected in Prince William Sound.

Estimating the impact of humpback whale predation on herring

In the past we found a correlation between the numbers of individual whales identified each year in PWS (this includes data from both standardized surveys and opportunistic efforts) and the mile-days of milt as reported by ADF&G surveys (Haught and Moffitt) and the HRM program (Fig. 7).

However, 2020 proved to be an exception. Whale numbers did not increase with the increase with the mile-days of milt. We are uncertain as to why humpback whales have failed to return to PWS following the marine heatwave, but their absence may provide some reprieve from predation pressure to local herring stocks.

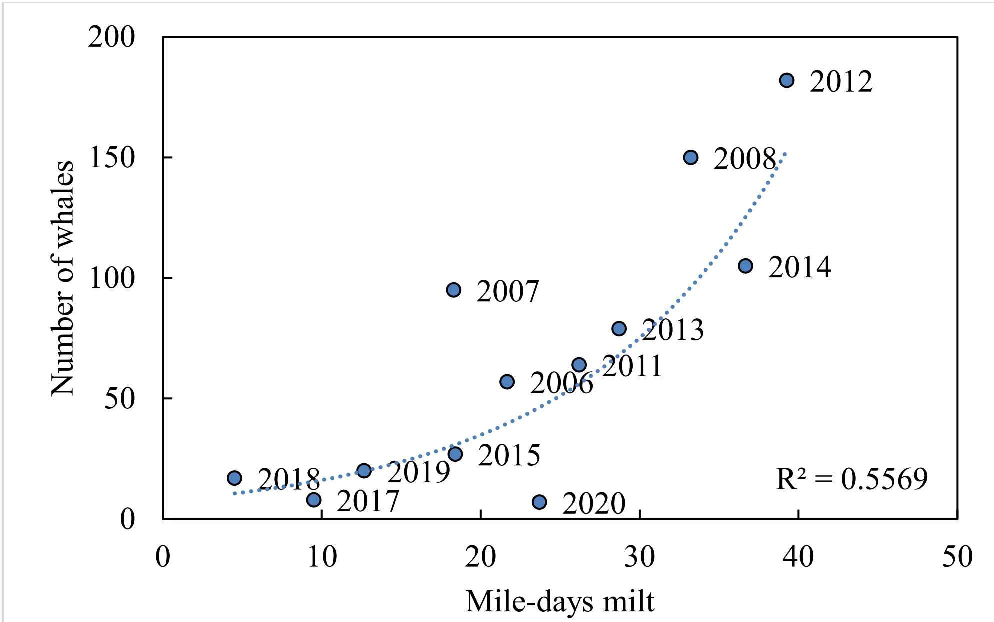

Figure 7. The number of individually identified humpback whales and mile-days of milt for Prince William Sound, 2007-2020. Herring data are courtesy of Scott Pegau (Prince William Sound Science Center) and Stormy Haught (Alaska Department of Fish and Game).

8. Coordination/Collaboration:

A. Long-term Monitoring and Research Program Projects

1. Within the Program

Our September 2020 IPP survey is typically a collaborative effort with the forage fish (20120114-C, PIs Arimitsu and Piatt) and fall and winter marine bird (20120114-E, PI Bishop) projects. Due to COVID-19 the forage fish and marine bird surveys did not take place.

We exchange killer whale and humpback whale sighting data with the killer whale project (20120114-N, PI Matkin).

2. Across Programs

a. Herring Research and Monitoring

We coordinate with HRM program lead Scott Pegau regarding herring predation by whales. The HRM program provided whale information during the spring when our survey was cancelled due to COVID-19.

b. Data Management

This project coordinates with the data management program by submitting data and preparing metadata for publication on the Gulf of Alaska Data Portal and DataONE within the timeframes required.

B. Individual Projects

We provide fluke photographs to Ted Cheeseman (the North Pacific humpback whale photo ID study group).

We provide sighting data to a University of Alaska Southeast study on stress hormones in humpback whales.

C. With Trustee or Management Agencies

We contribute a whale abundance indicator to the National Oceanic and Atmospheric Administration's (NOAA's) Gulf of Alaska Ecosystem Status Report to the North Pacific Fisheries Management Council (Ferriss and Zador 2020) - Fall Surveys of Humpback Whales in Prince William Sound.

9. Information and Data Transfer:

A. Publications Produced During the Reporting Period

1. Peer-reviewed Publications

Arimitsu, M., J. Piatt, S. Hatch, R. Suryan, S. Batten, M.A. Bishop, R. Campbell, H. Coletti, D. Cushing, K. Gorman, R. Hopcroft, K. Kuletz, C. Marsteller, C. McKinstry, D. McGowan, J. Moran, W.S. Pegau, A. Schaeffer, S. Schoen, J. Straley, and V. von Biela. 2021. Heatwave-induced collapse of forage fish species disrupts energy flow to top pelagic predators. Global Change Biology. https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.15556

Suryan, R.M., M.L. Arimitsu, H.A. Coletti, R.R. Hopcroft, M.R. Lindeberg, S.J. Barbeaux, S.D. Batten, W.J. Burt, M.A. Bishop, J.L. Bodkin, R.E. Brenner, R.W. Campbell, D.A. Cushing, S.L. Danielson, M.W. Dorn, B. Drummond, D. Esler, T. Gelatt, D.H. Hanselman, S.A. Hatch, S. Haught, K. Holderied, K. Iken, D.B. Iron, A.B. Kettle, D.G. Kimmel, B. Konar, K.J. Kuletz, B.J. Laurel, J.M. Maniscalco, C. Matkin, C.A.E. McKinstry, D.H. Monson, J.R. Moran, D. Olsen, W.A. Palsson, W.S. Pegau, J.F. Piatt, L.A. Rogers, N.A. Rojek, A. Schaefer, I.B. Spies, J.M. Straley, S.L. Strom, K.L. Sweeney, M. Szymkowiak, B.P. Weitzman, E.M. Yasumiishi, and S.G. Zador. *In press*. Ecosystem response persists after a prolonged marine heatwave. Scientific Reports.

2. Reports

Arimitsu, M., J. Piatt, R. Suryan, S. Batten, M.A. Bishop, R. Campbell, H. Coletti, D. Cushing, K. Gorman, S. Hatch, S. Haught, R. Hopcroft, K. Kuletz, C. Marsteller, C. McKinstry, D. McGowan, J. Moran, W.S. Pegau, A. Schaeffer, S. Schoen, J. Straley, and V. von Biela. 2020. Synchronous collapse of forage species disrupts trophic transfer during a prolonged marine heatwave. In: The Pacific Marine Heatwave: Monitoring During a Major

Perturbation in the Gulf of Alaska. Long-Term Monitoring Program (Gulf Watch Alaska) Synthesis Report *Exxon Valdez* Oil Spill Trustee Council Program 19120114 (Eds: Suryan, R.M., M.R. Lindeberg, and D.R. Aderhold). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Moran, J., and J. Straley. 2020. Long-term monitoring of humpback whale predation on Pacific herring in Prince William Sound. *Exxon Valdez* Oil Spill Restoration Project Annual Report (Project 19120114-O), *Exxon Valdez* Oil Spill Trustee Council, Anchorage, AK.

Moran, J., and J. Straley. 2020. Fall Surveys of Humpback Whales in Prince William Sound *in* Ferriss, B., and S.G Zador (eds), Ecosystem Status Report 2020: Gulf of Alaska. Report to the North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501. https://apps-afsc.fisheries.noaa.gov/REFM/docs/2020/GOAecosys.pdf

Suryan, R., M. Arimitsu, H. Coletti, R. Hopcroft, M. Lindeberg, S. Batten, M.A. Bishop, R. Brenner, R. Campbell, D. Cushing, S. Danielson, D. Esler, T. Gelatt, S. Hatch, S. Haught, K. Holderied, K. Iken, D. Irons, D. Kimmel, B. Konar, B. Laurel, J. Maniscalco, C. Matkin, C. McKinstry, D. Monson, J. Moran, D. Olsen, S. Pegau, J. Piatt, L. Rogers, A. Schaeffer, S. Straley, K. Sweeney, M. Szymkowiak, B. Weitzman, J. Bodkin, S. Zador. 2020. Ecosystem response to a prolonged marine heatwave in the Gulf of Alaska. *In*: The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Long-Term Monitoring Program (Gulf Watch Alaska) Synthesis Report *Exxon Valdez* Oil Spill Trustee Council Program 19120114 (Eds: Suryan, R.M., M.R. Lindeberg, and D.R. Aderhold). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

3. Popular articles

Moran, J. 2020. What Happened to the Whales? Delta Sound Connections. Prince William Sound Science Center.

B. Dates and Locations of any Conference or Workshop Presentations where EVOSTC-funded Work was Presented

1. Conferences and Workshops

Arimitsu, M., J. Piatt, S. Hatch, R. Suryan, S. Batten, M. Bishop, R. Cambell, H. Coletti, D. Cushing, K. Gorman, R. Hopcroft, K. Kuletz, C. Marsteller, C. McKinstry, D. McGowan, J. Moran, S. Pegau, A. Schaeffer, S. Schoen, J. Straley, and V. von Biela. 2021. Heatwave-induced synchrony within forage fish portfolio disrupts energy flow to top pelagic predators. Poster Presentation. Alaska Marine Science Symposium, Anchorage, AK. 26-28 January.

LaBua, S., K. Boswell, J. Vollenweider, and J. Moran. 2021. The decline of acoustic backscatter associated with overwintering herring (*Clupea pallasii*) in Lynn Canal, Alaska. Poster Presentation. Alaska Marine Science Symposium, Anchorage, AK. 26-28 January.

Moran, J., and J. Straley. 2020. Observations on humpback whales in Prince William Sound and Southeast Alaska following a marine heatwave. SPLASH-2 Virtual Workshop 1-3, December.

Moran, J., and J. Straley. 2020. Observations on humpback whales in Prince William Sound and Southeast Alaska following a marine heatwave. US Biologically Important Areas II Startup Virtual Workshop 8 & 9, December.

Pearson, H., S. Atkinson, J. Maselko, J. Moran, M. Rogers, and S. Teerlink. 2021. Humpback whales and tourism in Juneau, AK Establishing Baseline Measurements during the Covid 19 Pandemic. Oral Presentation. Alaska Marine Science Symposium, Anchorage, AK. 26-28 January.

2. Public presentations

Moran, J. 2020. What happens in Alaska doesn't stay in Alaska. Whale Tales, Kapalua, Hawaii. 14-17 February.

Moran, J. 2020. Large whale entanglements in Alaska and fisheries interactions. University of Alaska College of Fisheries and Ocean Sciences seminar series. Juneau, AK. 6 March.

Moran, J. 2020. Large whale entanglements in Alaska and fisheries interactions. University of Alaska Southeast marine mammal class. Juneau, AK. 7 April.

Moran, J. 2020. How are the whales responding to fewer tourists in the waters off Juneau, AKL Summer survey underway to learn more – Post 1. NOAA Fisheries Science Blog. https://www.fisheries.noaa.gov/science-blog/how-are-whales-responding-fewer-tourists-waters-juneau-ak-summer-survey-underway-learn.

Moran, J. 2020. Global check in speaker. Whale Tales. https://www.whaletales.org/.

Nicklin, F. 2020. Humpback chronicles, episode 39 – John Moran. Whale Trust. https://www.youtube.com/watch?v=FDNZk0Np64k

C. Data and/or Information Products Developed During the Reporting Period, if Applicable

The Prince William Sound Fluke Catalog has been updated through September of 2020.

Our PWS Fluke Catalog has been uploaded to Happywhale (Ted Cheeseman), the North Pacific humpback whale photo identification study group, for a basin wide study on humpback whales. https://happywhale.com/home.

D. Data Sets and Associated Metadata that have been Uploaded to the Program's Data Portal

Moran, J.R., and J.M. Straley. 2019. Lipid Analyses for Pacific Herring, Invertebrates and Humpback Whales in the Gulf of Alaska, 2017-2019, Gulf Watch Alaska Pelagic Component. Dataset. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Research Workspace.

Moran, J.R., and J.M. Straley. 2019. Significance of Whale Predation on Natural Mortality Rate of Pacific Herring in Prince William Sound, Alaska: 2017-2019, Gulf Watch Alaska Pelagic Component. Dataset. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Research Workspace.

Moran, J.R., and J.M. Straley. 2019. Dall's and Harbor Porpoise Survey Data, Prince William Sound, Alaska: 2017-2019, Gulf Watch Alaska Pelagic Component. Dataset. *Exxon*

Valdez Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Research Workspace.

Moran, J.R., and J.M. Straley. 2019. Castaway CTD Data, Prince William Sound, Alaska: 2017-2019, Gulf Watch Alaska Pelagic Component. Dataset. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Research Workspace.

10. Response to EVOSTC Review, Recommendations and Comments:

Science Panel Comment (FY21): What is the status of the spring survey that was rescheduled for fall/winter? If they will not occur, what is the contingency plan? Is there any prior experience in surveying whales and herring in that time of year that may serve as a reference level?

GWA PI Response (FY21): We were unable to complete the spring survey due to COVID-19 restrictions but did complete the September 2020 whale survey. While the spring survey is important for determining whale abundance and predation on spawning herring, the fall survey provides our longest time series of abundance trends. We plan on meeting all our obligations for year 5 of this funding cycle (FY21). If the COVID-19 situation in FY21 improves, we could add an additional survey with unused funds to capture seasonal trends in whale numbers. If we miss a field survey due to COVID-19, we would like to roll over unspent funds to fill this gap in FY22.

We have completed 7 spring surveys in Prince William Sound and have a sense of what whale numbers should be during the herring spawn. Observations made by the herring tagging team, aerial surveys, and ADF&G indicate that whale numbers remained low during the 2020 spawn. Although not directly comparable, preliminary results from the fall survey that was just completed indicates whale abundance is low, possibly an increase from 2019, but still below pre-marine heatwave levels, which is consistent with herring abundance trends in PWS.

A bioenergetic model is mentioned in the abstract but there appears to be no further mention of it in the proposal. The SP expected to see the data integrated into the model being that this is the final year of the project, and we also expect that this will be challenging. If this was not done, then explanation of why it was not is requested. The SP hopes that it was done and requests a description of the results.

GWA PI Response (FY21): The bioenergetics model will be done after all field and lab work has been completed in monitoring year 10 (FY21) as planned. We failed to highlight this in the Work Plan. The bioenergetic model will be similar to the model used in monitoring year 5 (Moran et al. 2018 and Straley et al. 2018):

Moran, J. R., et al. 2018. Regional variation in the intensity of humpback whale predation on Pacific herring in the Gulf of Alaska. Deep Sea Research Part II: Topical Studies in Oceanography 147:187-195.

Straley, J. M., et al. 2018. Seasonal presence and potential influence of humpback whales on wintering Pacific herring populations in the Gulf of Alaska. Deep Sea Research Part II: Topical Studies in Oceanography 147:173-186.

GWA PI Response (FY21): The proposal indicates top-down control of herring by the whales. What is the support for this mechanism? If this is really true, when whale counts went down in 2014 and 2015, wouldn't you expect that this would have been associated with an increase in herring numbers? The write-up gives the impression that both top-down and bottom-up controls are being argued at the same time. It is important to reconcile the importance of a whale effect in the herring modeling. Is such an effect supported by the model using available data? The treatment of the whale-herring relationship should be consistent across the whale and herring modeling proposals. There may be some room here for discussion among the PIs and integration of efforts. Please reconcile.

GWA PI Response (FY21): Whale numbers did not go down in 2014 and 2015, they remained high through April 2015 (Fig. 1). The opposite occurred; September 2014 had the highest count of whales that we have seen in Prince William Sound. In 2015 herring abundance dropped again (Fig. 2). We hypothesize that poor conditions in the Gulf of Alaska led to an influx of pelagic predators into the Sound, increasing top down forcing on herring. Unfortunately, there were no funded whale surveys until September of 2017, when we found that whale numbers had dropped significantly. Prior to the North Pacific marine heatwave, humpbacks focused on spring and fall aggregations of adult herring in Prince William Sound. Post heatwave, we saw increased pressure on young of the year and juvenile herring from the whales that remained in the Sound. This may have contributed to lower herring recruitment.

To see a recovery in herring numbers we need decent survival from egg to juvenile stages, which we suspect would be driven by bottom up processes. Once herring reach a size that they can form small schools, they become vulnerable to whale predation. In 2017-19, we observed increased predation by whales on age-0 herring. Age-0 herring are a low-quality food relative to adults, requiring whales to eat more mass for the same caloric gain. Our modeling effort should shed light on the impact of whale predation on juvenile herring in Prince William Sound (i.e., is their predation great enough to impact herring recruitment?).

We agree that we could improve coordination between the herring program and the Integrated Predator Prey team, we have made efforts to do so and will make it a priority in the future, especially because our data have now matured over a longer time period.

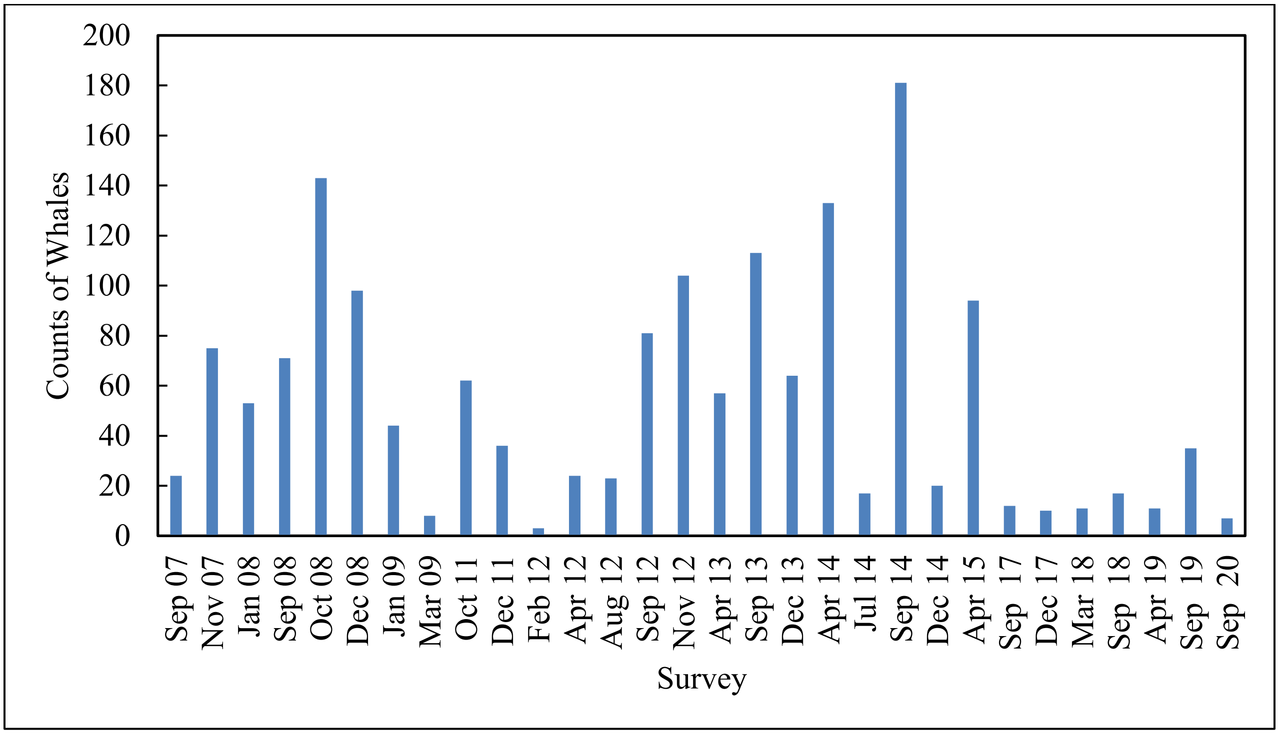

Figure 3. Counts of humpback whales in Prince William Sound provide an index of whale abundance, recent declines in whale numbers correspond to declines in herring biomass.

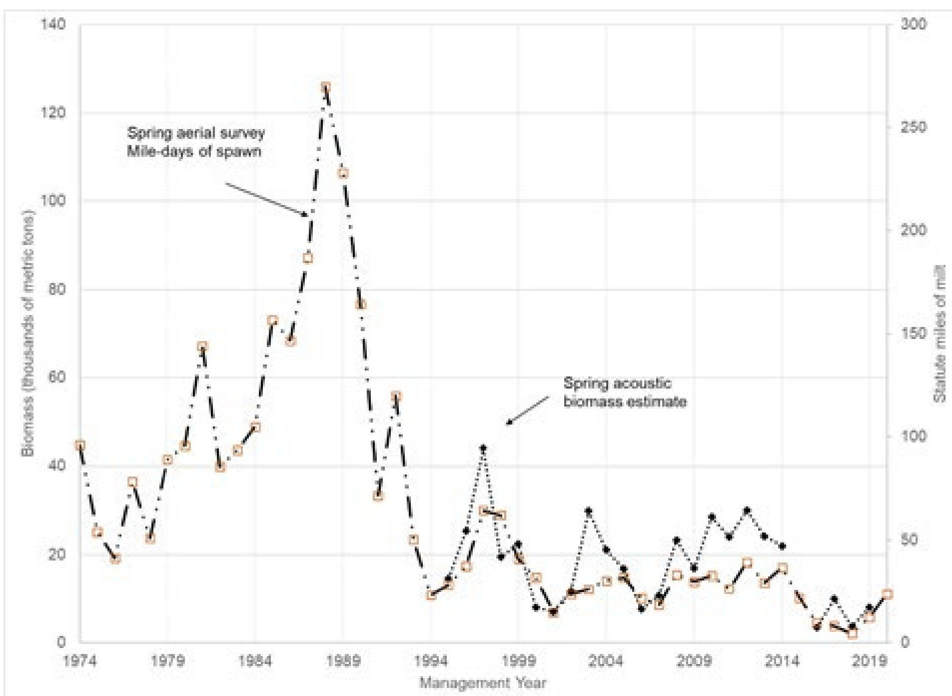

Figure 2. Herring increasing in Prince William Sound, but still not to pre-heatwave levels. (From the Herring Research and Monitoring program (Pegau, Haught, and Trochta) 2020 Ecosystem Status Report contribution.

GWA PI Response (FY21): The SP had a hard time separating the goal of the project from the broader Integrated Predator-Prey project. On page 6, overall project objective 2 addresses chemical analyses. Is this part of the whale project? If so, this raises follow-up questions on what was done, what was found, etc.

GWA PI Response (FY21): Knowing the quality of prey feeds into our energetic model and allows us to estimate the removal of prey species by whales. The Auke Bay Laboratory analyzes stable isotopes and energy density on prey items collected by both the whale and forage fish project. Understanding prey quality is crucial for interpreting changes in predator/prey dynamics. For example: we have seen a change in the composition of euphausiids in Prince William Sound. Species such as *Thysanoessa raschii* and *T. inermis* have dropped out of our samples while *Euphausia pacifica* and *T. spinifera* have increased. The species are not equal in their isotopic signatures and caloric value.

GWA PI Response (FY20): The Panel would like the PIs to discuss: if there's a decrease in predation of herring in humpback whales, what age-class of herring would that affect and when would one expect to see a response in the herring population? These questions should be addressed and interpreted, not just in these comments but in future proposals and reports. We emphasize the inclusion of interpretation and discussion of data (not necessarily analyses), in the proposal.

GWA PI Response (FY20): This is an interesting question and knowledge of the biology of herring and whales is needed to fully address this question. Adult herring have a higher energy density than juveniles and form large, dense shoals during spawning and overwintering. Adult herring have been the preferred prey for humpback whales in Prince William Sound (PWS). Humpback whales follow overwintering herring into PWS in September through Montague Strait and then to Port Gravina through the winter and spring when spawning occurs. We have found ~200 whales feeding on large schools of herring in the early study years (2007-2014) and have more than 400 individual whales in our catalog. We have documented all age classes of herring being consumed by whales. The 2017-18 decrease in herring predation by whales parallels the dramatic decline of herring in PWS (Fig. 1 below).

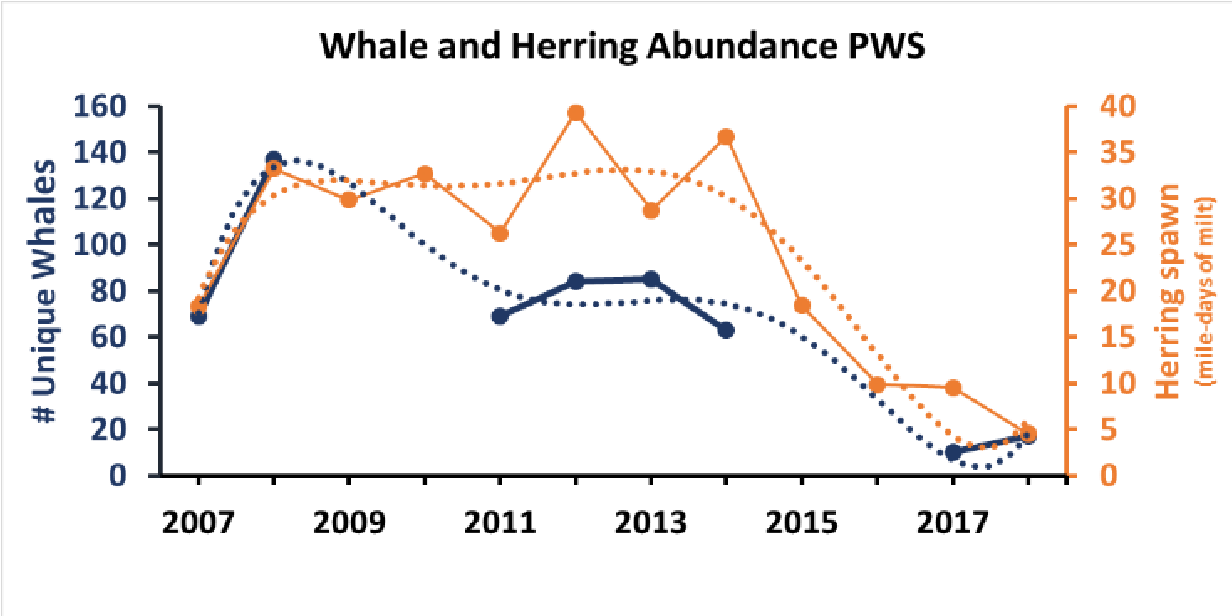

Figure 1 (Fig. 7 in our 2018 annual report). In PWS the humpback whale decline parallels the herring decline, their major food source. Miles-day herring spawn is used as an annual indicator for change in herring abundance. The trajectory could indicate a carrying capacity with a plateau, then steep decline (with a bit of a lag) during the marine heatwave (that never fully dissipated in the Gulf of Alaska, and re-intensified in 2018).

Humpback whales in PWS rely on adult herring as their primary prey in the fall and winter. With herring biomass at record lows in 2017-2018 far fewer whales (less than 20) were present in the same areas where up to ~200 whales had been documented feeding each year on herring during 2007-2014. However, when adult herring are scarce, we see a switch to age zero, one, and two year old herring. Younger herring form small, disperse schools which require increased foraging cost for the whales resulting in a lower energetic return. Whales increased their predation on juvenile herring beginning in 2015.

There has been insufficient recruitment of herring to determine what age structure would be most impacted by whale predation. The Gulf Watch Alaska integrated predator-prey surveys and the Herring Research and Monitoring program will discuss the possibility of determining answers to some of these questions. In the future, further discussion and the inclusion of interpretation of data will be addressed in proposals.

GWA PI Response (FY20): In Figure 1 of the proposal regarding the index on whale abundance: has there been a shift in whale distribution in recent years? It is important to try to distinguish changes in abundance with changes in distribution to the extent possible. The high variability in whale counts between sampling periods cannot be explained by whale population dynamics alone. There appears to be a seasonal signal in the counts, although this may not be a fixed effect. We would like to see mark and recapture methods applied to generate population estimates with confidence intervals, such as those used in Teerlink et al. (2015) to assess population estimates.

GWA PI Response (FY20): There has not been a shift in distribution within PWS, but an actual decline in numbers of whales sighted. Our effort and track lines have been consistent and cover most of the sound. Similar declines in humpback whale numbers have also been documented in Southeast Alaska. Neither of these regions are closed populations and there is potential that whales that generally feed in PWS are foraging elsewhere in the Gulf of Alaska. We are connected with a network of researchers in the North Pacific, including Hawaii and the California Current to determine if whales that formerly fed in PWS are now feeding elsewhere, or potentially deceased. We recently submitted the PWS humpback whale catalog to an automated matching program (happywhale.com) to see if these whales have been feeding elsewhere in the North Pacific. Both PIs are leading working groups to determine declines in humpback whale numbers on the breeding grounds and in Alaska are the result of migration or mortality.

The variability among surveys is due to the behavior and biology of humpback whales. These are seasonal migrants that generally winter in tropical waters and feed in higher latitudes. The departure from feeding areas is staggered with some whales leaving early and some later, with some returning from the wintering areas earlier and some later. There also are some whales overwintering in higher latitudes. On the feeding areas, humpback whales are dispersed in summer and aggregate in the fall when herring come into deep bays and fjords to overwinter. Thus, a seasonal peak is evident in the fall and a seasonal low is evident in the winter, with numbers increasing in spring as whales return. The very low numbers in 2017 in September were alarming and persisted into 2018. A September survey is currently underway and we will soon know if conditions are staying the same or changing.

We will apply a mark-recapture model to these data, as we did for our earlier data (Straley et al. Deep-Sea Research Part II 147 (2018) pp. 173–186). As stated in our methods to assess the impact of predation more information is needed than an abundance estimate as described in our paper:

"Although mark-recapture models provide an estimate of abundance, they do not describe seasonal trends. Consequently, we used the number of unique whales seen each month for establishing seasonal patterns, then adjusted the pattern to account for the estimated number of whales present. The data used to describe the seasonal attendance pattern, included calves because by fall calves have become intermittently independent and become more independent with age (Straley, unpublished data). By fall calves were feeding on the same prey as other whales. We also included individuals identifiable in poor quality images. This number represents a lower bound to the daily attendance pattern for whales in each location. Daily attendance was estimated by fitting linear models to the observed numbers. Inflection points for linear models were determined visually. We used the attendance patterns to establish a lower bound (as described above) and the Huggins estimate of abundance to establish the upper bound to the whale attendance pattern."

Keep in mind the Teerlink et al. (2015) data were collected in a very small area of PWS in the summer and no data on prey were collected. The purpose was very different from our study. We are addressing how many whales each day are foraging on herring. While knowing how many whales in a season are present is relevant for some questions, that number provides little detail on day to day foraging. Also, we are studying this population of whales that mostly leaves during the winter (although a few overwinter), then returning in spring and they are often different whales. Hence, immigration and emigration are huge issues, which violates the basic assumptions of mark recapture models.

11. Budget:

Please see provided program workbook. Humpback whale survey work in 2020 was compromised by the COVID-19 pandemic and we were unable to conduct a spring survey due to travel restrictions. In addition to disruptions of fieldwork, there were also delays in the chemical analysis of prey samples. As a result, several categories of our budget are underspent. We plan to make up the spring survey at a later date when COVID -19 restrictions ease.

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
PROGRAM PROJECT BUDGET PROPOSAL AND REPORTING FORM

Budget Category:	Proposed FY 17	Proposed FY 18	Proposed FY 19	Proposed FY 20	Proposed FY 21	TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel	$6.0	$0.6	$0.6	$0.6	$0.6	$8.4	$12.1
Travel	$7.8	$7.8	$7.8	$7.8	$7.8	$39.0	$28.0
Contractual	$119.7	$119.8	$149.5	$146.7	$136.5	$672.3	$412.3
Commodities	$15.0	$14.0	$14.0	$14.0	$17.5	$74.5	$26.8
Equipment	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
SUBTOTAL	$148.5	$142.2	$171.9	$169.1	$162.4	$794.2	$479.2
General Administration (9% of subtotal)	$13.4	$12.8	$15.5	$15.2	$14.6	$71.5	N/A
PROJECT TOTAL	$161.9	$155.0	$187.4	$184.4	$177.0	$865.7	
Other Resources (Cost Share Funds)	$220.0	$220.0	$120.0	$127.0	$127.0	$814.0	

LITERATURE CITED

Ferriss, B. and Zador (editors). 2020. Gulf of Alaska Ecosystem Status Report for 2020. NOAA Alaska Fisheries Science Center annual report to the North Pacific Fishery Management Council. https://apps-afsc.fisheries.noaa.gov/REFM/docs/2020/GOAecosys.pdf.