1. Program Number:

18120114-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, 2018-January 31, 2019

5. Date of Report:

April 1, 2019

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

During this reporting period we secured the last of the National Oceanic and Atmospheric Administration (NOAA) funds to cover vessel costs for our March 2018 & 2019 surveys. March surveys for 2020-2022 (the remainder of this 5-year funding period) will be supported by additional funds received from the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC). These surveys will allow us to continue our early spring monitoring efforts within PWS and maintain the time series which began in 2007. All sampling and chemical analysis has been completed during FY18, with the exception of prey stable isotopes, which were delayed due to the Federal government shutdown.

Trends in humpback whale abundance, diet, and distribution

We completed the fall Integrated Marine Predator-Prey (IMPP) survey with the fall/winter marine bird (18120114-E) and forage fish (18120114-C) projects and a NOAA funded whale-prey survey in mid-March. The trends seen in 2017 continued into 2018, with low numbers of humpback whales (Table 1) and marine birds, along with a reduced abundance of other forage fish and krill.

Table 1. Encounter rates of whales in PWS 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.

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

September of 2018 was our 8th fall survey. As in 2017, we failed to locate any major concentrations of humpback whales or prey (Fig. 1). The whales were targeting smaller, disperse, patches of prey with a shift towards young of the year and juvenile herring relative to earlier years. Anecdotal reports from the public and other research groups also noted the lack of humpback whales in PWS during the summer and fall of 2017 and 2018.

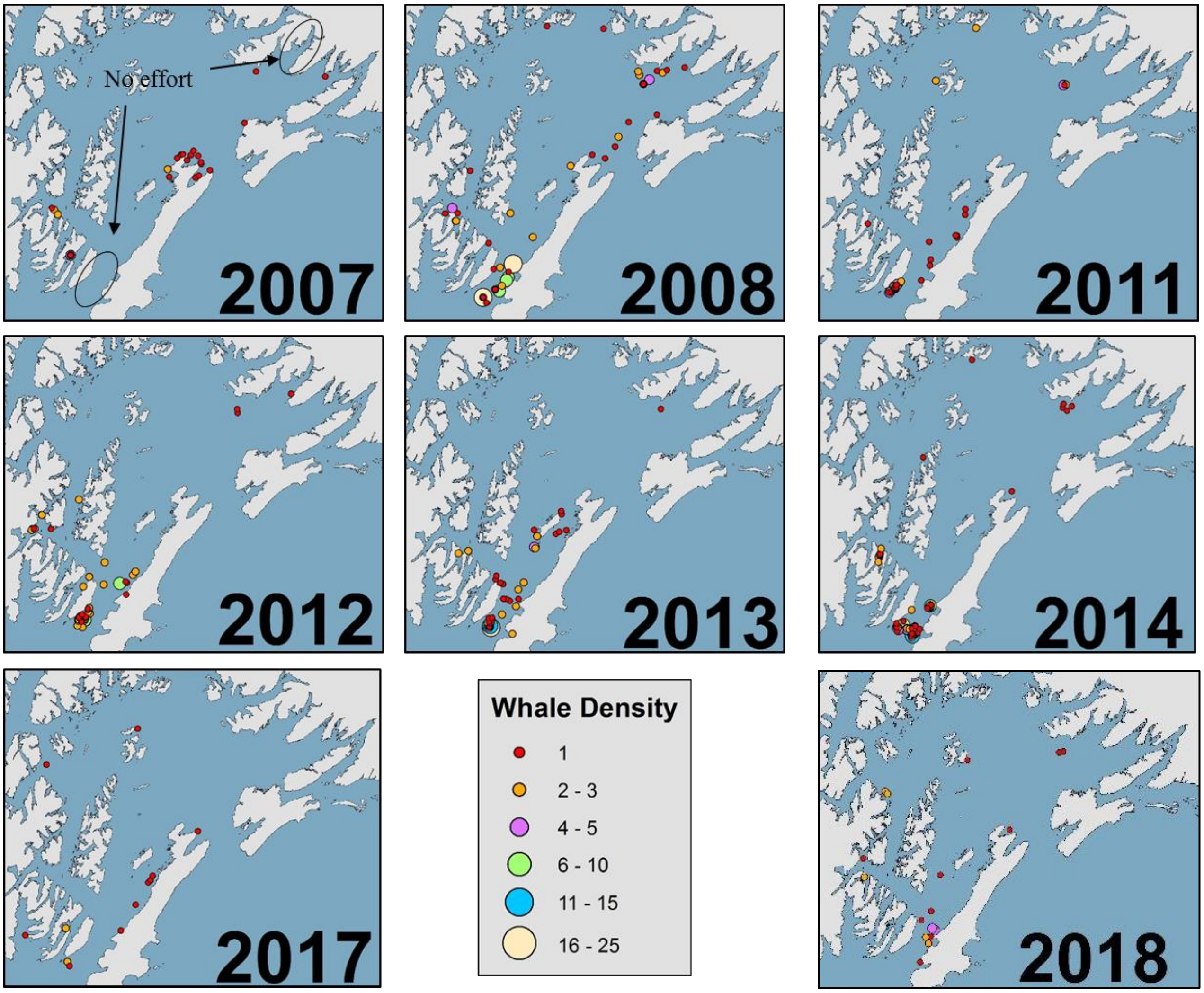

Figure 1. The distribution and abundance of humpback whales in PWS during September/October surveys. Note that Montague Entrance and Port Gravina were not surveyed in 2007.

During the March 2018 survey, a small group of whales and adult herring were located near Latouche Island, but overall counts of whales for this time of year remained low for early spring (Fig. 2). Port Gravina and Montague Strait were surveyed for forage fish and euphausiids using hydroacoustics. Forage species were collected and analyzed for energy density and stable isotopes.

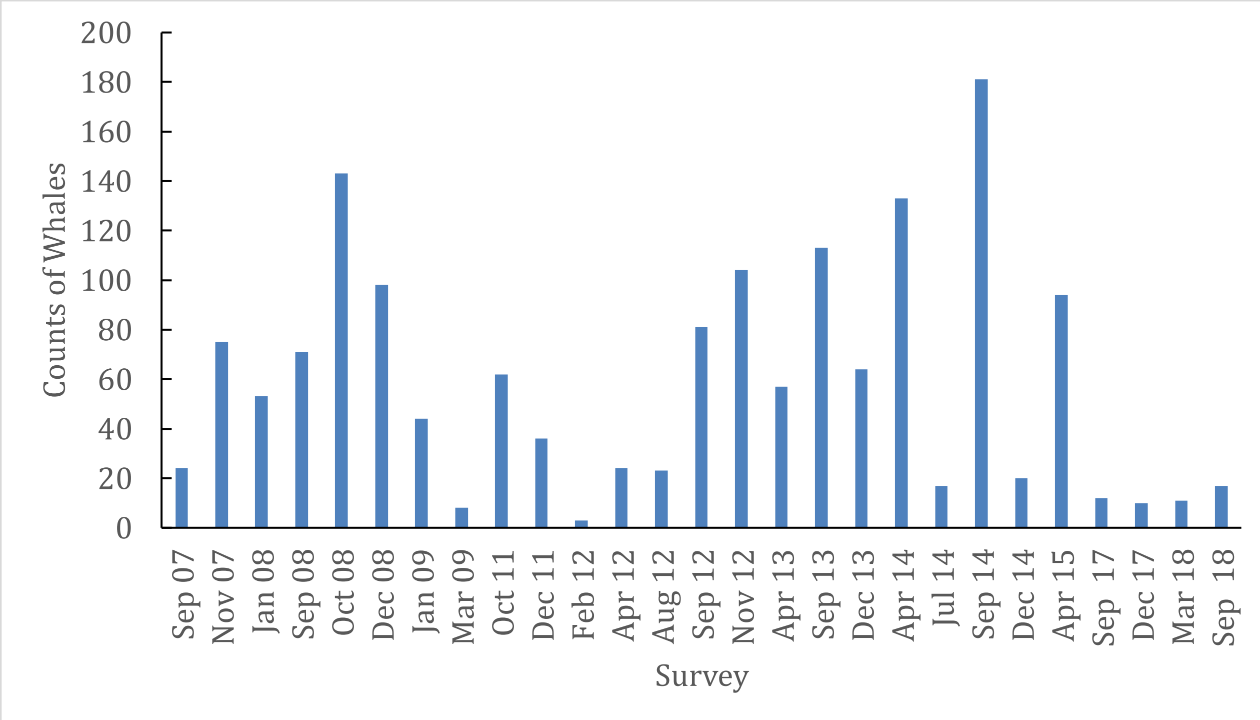

Figure 2. Counts of humpback whales during surveys in PWS.

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. As in 2017, based on plankton net sampling, we found that there may have been a shift it the species composition during 2018 to *T. spinifera* and *E. pacifica* replacing the typical common species (*T. longipes, T. inermis, and T. raschii*). Young of the year herring continue to be a relatively low quality prey for humpback whales (Fig. 3), with energy density varying by year and region (Fig. 4). We saw a decline in the energy density of juvenile herring (age 1 and 2) between 2014 and 2017 (Fig. 3).

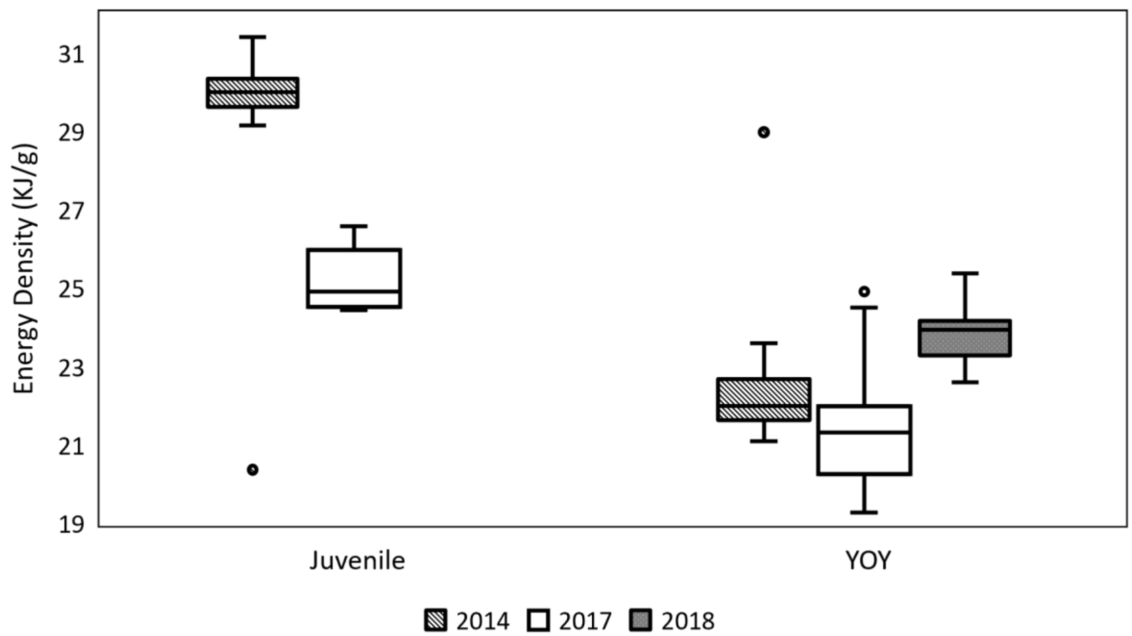

Figure 3. Energy density (KJ/g) of juvenile and young of the year pacific herring by year collected during fall surveys.

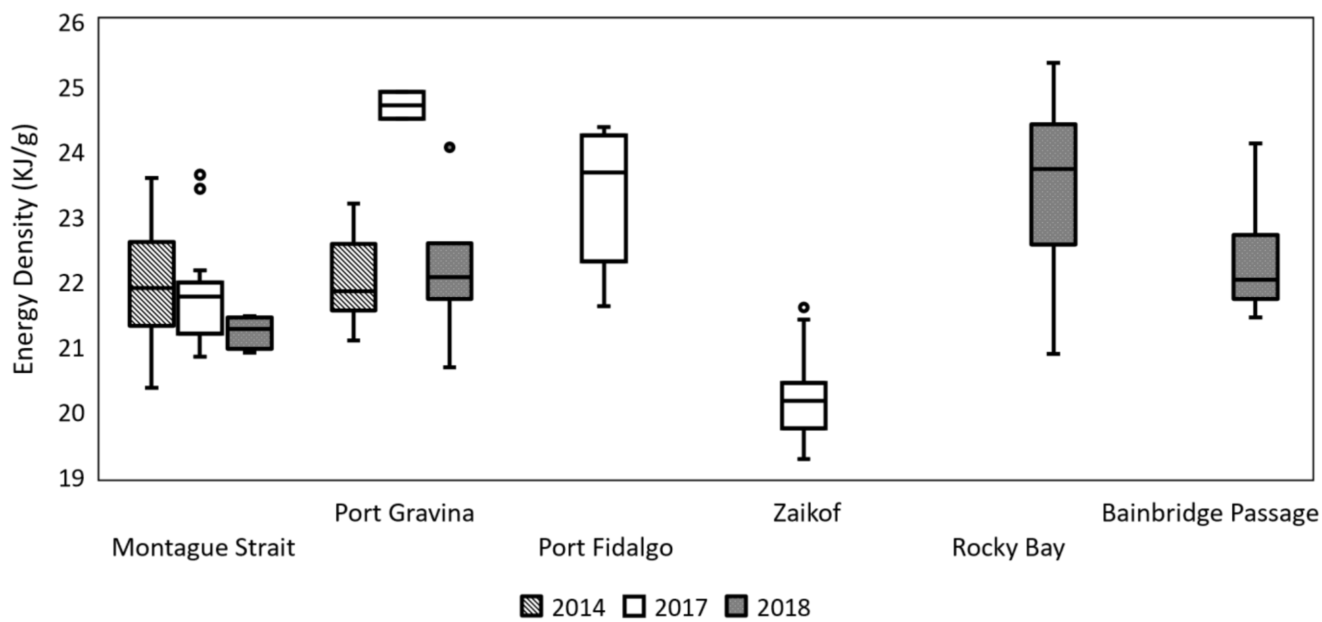

Figure 4. Energy density (KJ/g) of juvenile and young of the year pacific herring by year collected during fall surveys by region.

We examined the trophic position of potential humpback whale prey collected in PWS (Fig. 5). These data will be useful in interpreting changes in the prey field that may explain shifts in whale distribution and abundance.

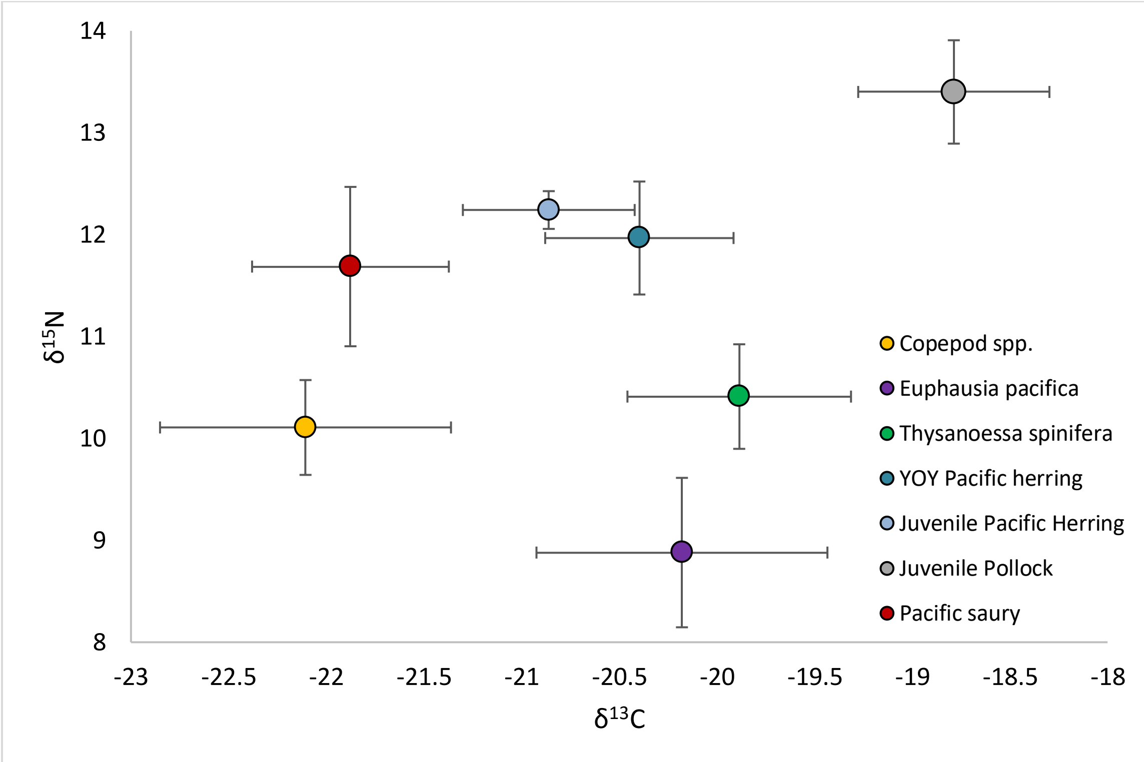

Figure 5. δ^{13}C and δ^{15}N of potential humpback whale prey in PWS.

We acquired baleen from two humpback whales stranded on Kayak Island in 2018 and can compare these to three other whales sampled in PWS. Baleen plates were sampled at 1 cm intervals following the axis of the longest individual baleen filament for carbon and nitrogen stable isotope analysis (Fig. 6). Previous studies in other baleen whale populations have shown an oscillating pattern of nitrogen isotope (^{15}N) enrichment and depletion along the length of individual baleen plates corresponding to the fasting and feeding states or changes in resource use associated with whales' migratory and reproductive feeding behavior (Matthews and Ferguson 2015). All the baleen plates analyzed in this study had a general oscillating pattern of ^{15}N enrichment and depletion occurring at roughly 12-20 cm intervals, within the bounds of previous estimates of annual baleen growth rates. There were slight deviations in this pattern which may result from individual whales' foraging or migratory behavior. All whales sampled from PWS were near the peak of the enrichment phase of ^{15}N oscillation, which likely means that they had not resumed substantial feeding upon their return to PWS and are metabolizing endogenous reserves. This may be due to stress from migration leading to changed foraging behavior, lack of prey resources being present, or other unknown factors.

It also appears that the three whales from within PWS (Latouche Island, Hogan Bay, and Naked Island), were feeding at a higher trophic level than the two from Kayak Island. Although preliminary, these results support our earlier finding that PWS whales are feeding primarily on fish.

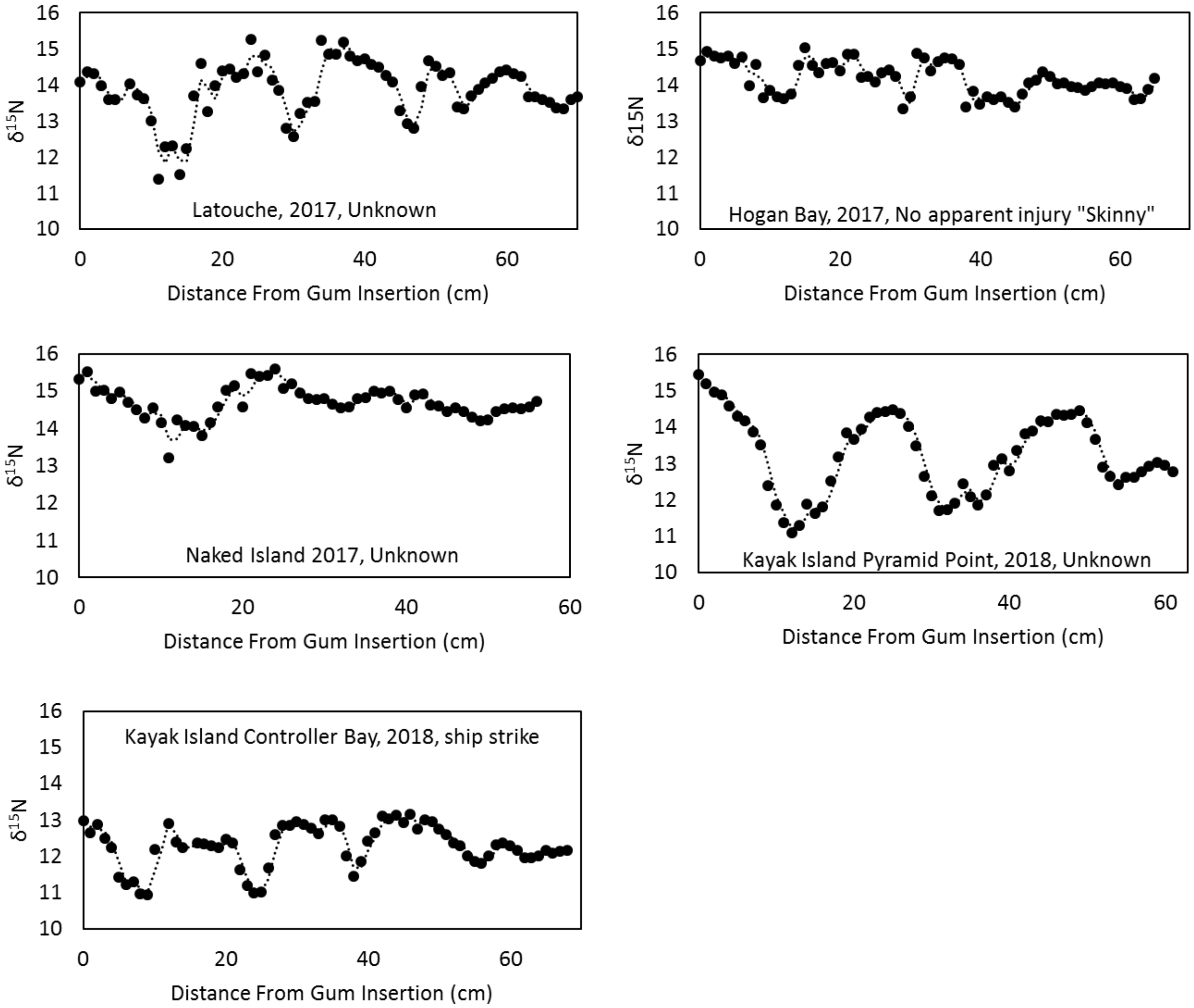

Figure 6. Stable nitrogen isotope measurements from baleen plates of humpback whales that stranded in Prince William Sound and the Northern Gulf of Alaska. Sampling distance from proximal end (base) of baleen plate is shown on the x-axis. Zero is the most recent sample, going back in time as length increases.

Estimating the impact of humpback whale predation on herring

Humpback whale abundance tracks the trends in herring biomass within PWS (Fig. 7). Our September PWS observations from 2017 and 2018 parallel our observations from northern Southeast Alaska, low whale numbers and few calves (Fig 8). Whales in both areas appear to target scattered prey (in many cases age 0 herring) rather than the large, dense aggregations of krill and adult herring that we have seen in the past.

During 2017 and 2018 the number of humpback whales on the breeding grounds in Hawaii was also reported to be low. This led to the formation of several working groups to identify the causes of the apparent decline. Data from our study and other GWA projects have been essential for researchers from Hawaii and Alaska in understanding declines in whale abundance.

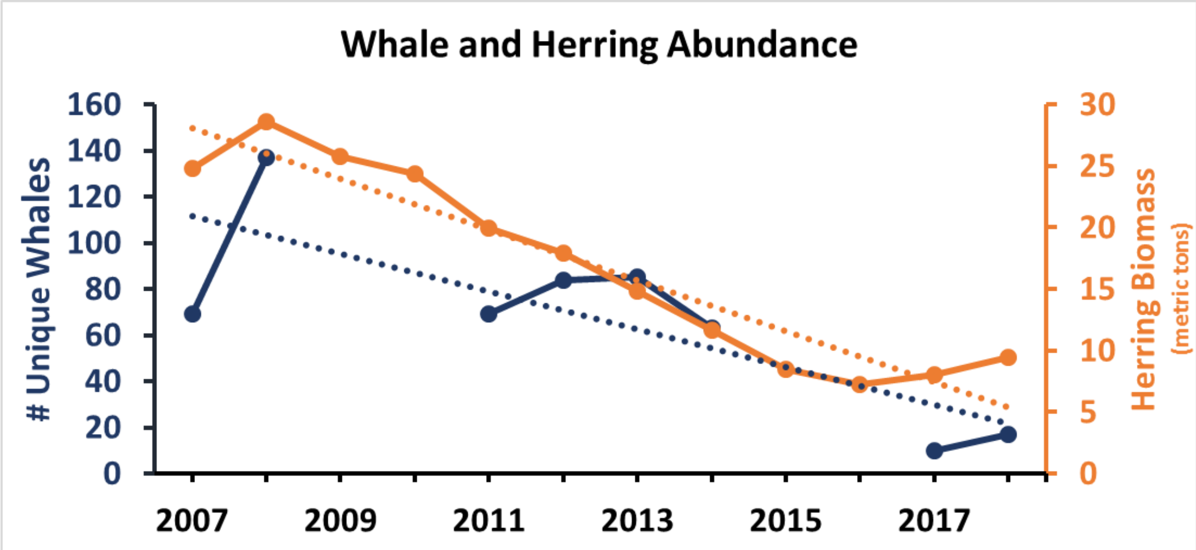

Figure 7. The number of individually identified humpback whales and herring spawning biomass in Prince William Sound, 2007-2018. Herring biomass data are courtesy of Scott Pegau (Prince William Science Center), Stormy Haught (Alaska Department of Fish and Game), John Trochta (University of Washington) and available in Zador, S. G., and E. M. Yasumiishi. 2018. Ecosystem Assessment. In: Ecosystem Considerations 2018: Status of the Gulf of Alaska Marine Ecosystem.

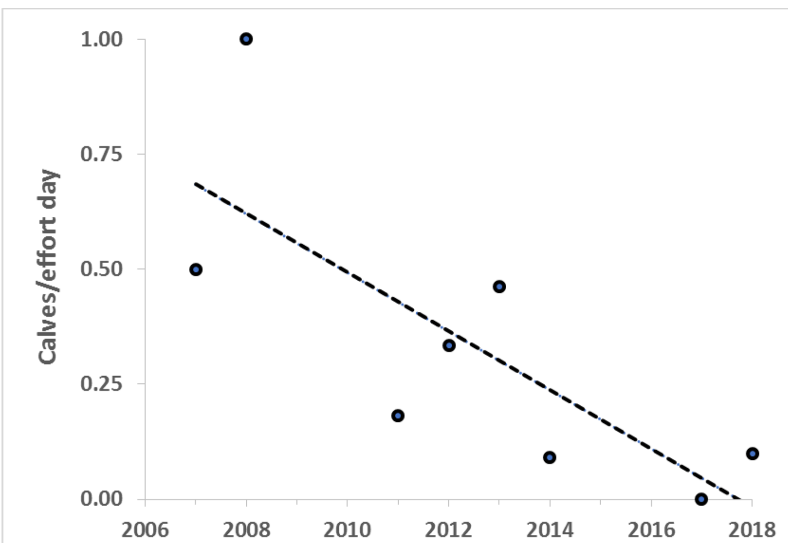

Figure 8. Encounter rate for humpback whale calves in PWS.

8. Coordination/Collaboration:

A. Projects Within a Trustee Council-funded program

1. Within the Program

Our September 2018 IMPP survey was a collaborative effort with the forage fish (18120114-C) and fall and winter marine bird (18120114-E) projects.

Samples were collected for the forage fish project (18120114-C) in March.

Killer whales were photographed for the killer whale project (18120114-N).

A sea otter head was collected for Dan Monson (USGS) of the nearshore project (18120114-H).

2. Across Programs

a. Herring Research and Monitoring

Kristen Gorman (Herring Research and Monitoring principal investigator) was on board for our September 2018 survey to collect herring for her project.

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.

c. Lingering Oil

N/A

B. Projects not Within a Trustee Council-funded program

N/A

C. With Trustee or Management Agencies

Harbor porpoise eDNA was collected for stock structure in collaboration with Kim Parsons (National Marine Fisheries Service [NMFS]/Marine Mammal Laboratory).

Young of the year pollock were collected for Louise Copeman (NOAA Cooperative Institute for Marine Resources Studies, Oregon State University).

Sea lion brands were photographed for Lauri Jemison (Alaska Department of Fish and Game).

We responded to a Minke whale stranding and received humpback whale baleen from Kate Savage (NMFS/Alaska Regional Office/Protected Resources Division).

Contributed two indices to NOAA's Gulf of Alaska Ecosystem Status Report to the North Pacific Fisheries Management Council (Zador and Yasumiishi 2018).

9. Information and Data Transfer:

A. Publications Produced During the Reporting Period

Moran, J. and J. Straley. 2019. Summer survey of population level indices for Southeast Alaska humpback whales and fall surveys of humpback whales in Prince William Sound *in* Zador, S. G., and E. M. Yasumiishi. 2018. Ecosystem Status Report 2018: Gulf of Alaska. Report to the North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99301. https://www.fisheries.noaa.gov/resource/data/2018-status-gulf-alaska-ecosystem

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

Presentations:

Moran, J., C. Gabriele, J. Neilson, K. Savage, and J. Straley. 2018. Recent observations of humpback whales in the Gulf of Alaska: carrying capacity or a cause for concern? Poster Presentation. Ocean Science Meeting, Portland OR. 11-16 February.

Straley, J. and J. Moran. 2018. Have Gulf of Alaska Humpback Whales Reached Carrying Capacity or Has the Blob Made the Food Web Screwy? Poster Presentation. Ocean Science Meeting, Portland OR. 11-16 February.

Moran, J. 2018. A whale of an update. Auke Bay Laboratory Mini Seminar. Juneau, AK. 4 April.

Moran, J. 2018. What do predators tell us about prey? Juneau Marine Naturalist Symposium. Juneau, AK. 10 May.

Suryan, R., M. Lindeberg, D. Aderhold, M. Arimitsu, J. Piatt, J. Moran, J. Straley, H. Colletti, D. Monson, S. Hatch, T. Dean, R. Hopcroft, S. Batten, S. Danielson, B. Konar, K. Iken, B. Laurel, R. Campbell, S. Pegau. 2018. Ecosystem variability and connectivity in the Gulf of Alaska following another major ecosystem perturbation. North Pacific Marine Science Organization (PICES) annual meeting, Yokohama, Japan. 25 October - 4 November.

Straley, J. 2019. Observations of humpback whales in Alaska. Trends in humpback whales meeting, Honolulu HI. 27-28 November.

Straley, J. 2019. Ecosystem implications for the decline in reproductive success in humpback whales in the Gulf of Alaska. Alaska Marine Science Symposium, Anchorage, AK. 28-31 January.

Outreach:

Moran, J. Dall's Porpoise: Life in the fast lane. Delta Sound Connections 2018-2019. Prince William Sound Science Center.

Dall's Porpoise Expands Territory in a Changing Prince William Sound. February 26, 2018. Feature Story. https://www.fisheries.noaa.gov/feature-story/dalls-porpoise-expands-territory-changing-prince-william-sound.

Dall's Porpoise Research in Alaska. NOAA Fisheries website. https://www.fisheries.noaa.gov/alaska/marine-mammal-protection/dalls-porpoise-research-alaska.

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

Moran, J. and J. Straley. 2018. Data contributed to the NOAA Ecosystem Status Report 2018 for the Gulf of Alaska region. Full reports may be found at the following link: https://access.afsc.noaa.gov/reem/ecoweb/.

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

Moran, J. R. and J. M. Straley, 2018. Lipid Analyses for Pacific Herring, Invertebrates and Humpback Whales in the Gulf of Alaska, 2017-2018, 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, 2018. Significance of Whale Predation On Natural Mortality Rate of Pacific Herring in Prince William Sound, Alaska: 2017-2018, 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, 2018. Dall's and Harbor Porpoise Survey Data, Prince William Sound, Alaska: 2017-2018, 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, 2018. Castaway CTD Data, Prince William Sound, Alaska: 2017-2018, 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 (EVOSTC FY18 Work Plan)**:** The Panel was excited to see the results presented in Figure 1 in the proposal and encourages the PIs to make comparisons to the relevant study conducted by the National Center for Ecological Analysis and Synthesis (NCEAS) working group. Results shown in Figure 1 of the proposal are important and so strikingly incompatible with what was suggested previously by the time series analysis of the NCEAS working group (Ward et al 2017). That working group's model, of necessity, made some quite restrictive assumptions. Can the PIs look at the NCEAS model, and consider whether the new findings invalidate one or more key conclusions from that synthesis work?

PI Response: Thank you for the close review of project 18120114-O's work plan. Comparisons to Ward et al. (2017) are problematic because these authors depend on summer whale counts from western PWS (Teerlink et al. 2014), while our project focuses on fall/winter and spring time periods when herring form large, dense schools that are most vulnerable to whale predation. Observations of whales and prey when herring are aggregated allow us to study the potential impact of foraging humpback whales on herring as a possible contributor to the lack of herring recovery. The following are three important differences between our approach and the Teerlink et al. (2014) approach to modeling whale predation on herring:

1. The Teerlink et al. (2014) study estimates the number of whales that use PWS in summer, not the number that are present at any given time (for example, 10 whales spending 90 days in the Sound would have the same effect on prey as 900 whales spending one day in the Sound). It is important to know how many whales are feeding on herring for how many days within the Sound and the Ward et al. (2017) paper does not address this.

2. Ward et al. (2017) used whale population estimates from summer surveys, when overall whale abundance is generally low in PWS compared to other seasons. Our work identified adult herring as the preferred prey of humpbacks in PWS, especially when herring are aggregated in the fall, winter, and spring (spawning); thus, whale numbers peaked in the fall and spring, and dropped during the summer months.

3. Neither Ward et al. (2017) nor Teerlink et al. (2014) identify prey consumed by humpback whales.

Additionally, the Panel is concerned that objective #3 may be overly ambitious and suggests re-wording and editing to "predation rate"?

With regards to objective #3 being overly ambitious and the Science Panel's suggestion of rewording and editing to "predation rate"? We agree and will change the wording of this objective.

11. Budget:

Please see provided program workbook.

The planned April 2019 survey will use FY18 funds because there is a lag in receiving FY19 funds. NOAA funds were used to secure vessel time for an additional March 2019 survey; however, NOAA funds are exclusively for vessel cost. Cost for logistics (travel, shipping, overtime) and data processing are covered by GWA funds.

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	$8.7
Travel	$7.8	$7.8	$7.8	$7.8	$7.8	$39.0	$19.4
Contractual	$119.7	$119.8	$149.5	$146.7	$136.5	$672.3	$168.3
Commodities	$15.0	$14.0	$14.0	$14.0	$17.5	$74.5	$10.3
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	$206.7
General Administration (9% of	$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	$120.0	$120.0	$800.0	

Literature Cited

Matthews, C. J. D., and S. H. Ferguson. 2015. Seasonal foraging behaviour of Eastern Canada-West Greenland bowhead whales: an assessment of isotopic cycles along baleen. Marine Ecology Progress Series 522:269-286.

Zador, S. G., and E. M. Yasumiishi. 2018. Ecosystem Status Report 2018: Gulf of Alaska. Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99301. https://www.fisheries.noaa.gov/resource/data/2018-status-gulf-alaska-ecosystem