NORTH GULF OCEANIC SOCIETY
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2022 Progress and Reduced Budget Proposal:
Killer Whale Monitoring Project

Objective: We are seeking support for continued but reduced funding of the Killer Whale Monitoring Project, which was proposed for funding in 2022-2031 as part of the Gulf Watch Long Term Research and Monitoring Program. The project was awarded a single year of funding in 2022, which has enabled expansion of our very successful research. This report provides an overview of our recent achievements and a preview of publications that are currently in preparation. We are providing these materials for review by the Trustee Council and to request funding for a further three years (FY23-25, see p12 for justification) at a reduced rate. This reduced rate is possible because we have secured partial funding from elsewhere, as recommended by the Trustee Council in 2021.

Background: The Killer Whale Monitoring Project was initiated in 1984 and has provided one of the few time series with pre-spill data. We primarily use non-invasive photo-identification to track the life history of individual killer whales and monitor their pods and populations. The structure of these populations has been elucidated by studies of their genetics and acoustics, and their ecological role studied through ongoing research on diet and distribution. We have documented the spill to have clear, long-term and continuing effects on killer whales that were exposed. The AB pod of southern Alaska Resident killer whales has not recovered and the AT1 Transient population is headed for extinction. AB pod was on 30+ year recovery trajectory since the spill, but, along with other Resident pods, has declined following the recent marine heatwave in the Gulf of Alaska. This demonstrates the need to continue monitoring to assess recovery potential, and to understand the influence of environmental drivers. In 2021 the Science Panel recommended that our valuable datasets could be used to facilitate a broader ecosystem understanding. In response, we proposed new field and analytical methods to build on our existing time series. Specifically, we are now using non-invasive drone photogrammetry to track short-term changes in body condition and growth, and are linking these health metrics to demography to help understand longer-term population changes. Importantly, this will allow us to better integrate with synthesis efforts by the Gulf Watch Program as our photogrammetry measurements directly relate to killer whale nutritional health, which is relevant to the status of lower trophic levels in the food web on which these apex predators depend.

Contents

Declines in survival and fecundity of fish-eating killer whales indicate abrupt and prolonged ecosystem impacts of a marine heatwave in the Gulf of Alaska

Since the 1980s we have used photo-identification to document long-term increases in the abundance of fish-eating Resident killer whale (*Orcinus orca*) pods in the Gulf of Alaska (Matkin et al. 2014), although AB pod has not yet recovered to pre-spill levels following exposure (Matkin et al. 2008). In recent years the occurrence of Residents has declined in our coastal study areas in Prince William Sound and the Kenai Fjords, apparently responding to an intense marine heatwave in 2014-16 (Suryan et al. 2021). To assess the impacts of the heatwave at the population level, we fit a Bayesian latent state mark-recapture model to long-term photo-identification records to estimate annual departures from the survival expected based on age and sex composition for 2009-2021, spanning five years on each side of the heatwave. We also modelled departures in fecundity from the expectation given female ages, and investigated covariance in survival and fecundity in the same hierarchical Bayesian model (e.g. Ward et al. 2016). Three of eight pods showed significant declines in survival at the end of the heatwave, including the most abundant AJ pod and the strategically important AB pod. Furthermore, six of the eight showed reductions in fecundity that persisted for as many as five years due to disruption to the whales' slow reproductive schedules. This is important for understanding how environmental variation has and will affect recovery potential.

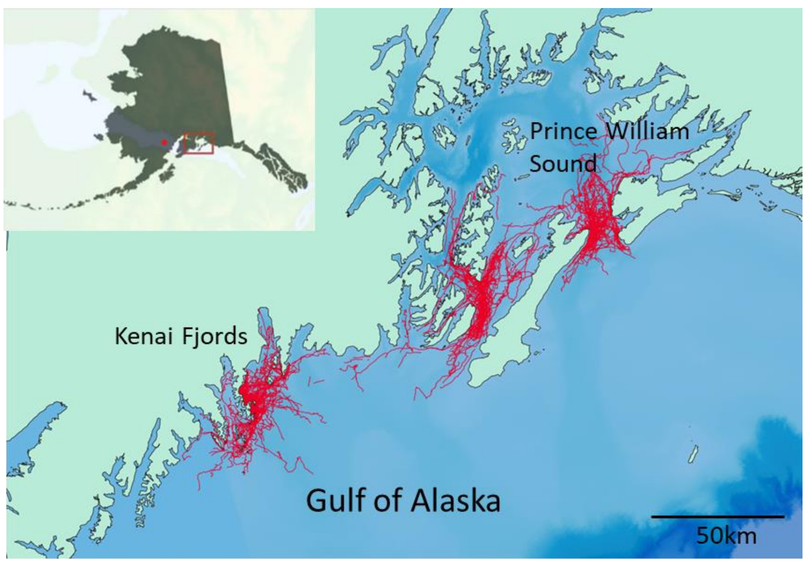

Figure 1: Study area in the coastal waters of Prince William Sound and Kenai Fjords, Gulf of Alaska. Red lines indicate tracks of our research vessel when with Resident killer whales collecting photo-identification images, 2009-2021. These years were selected for this analysis to provide data for five years either side of the 2014-2016 marine heatwave in the Gulf of Alaska.

References

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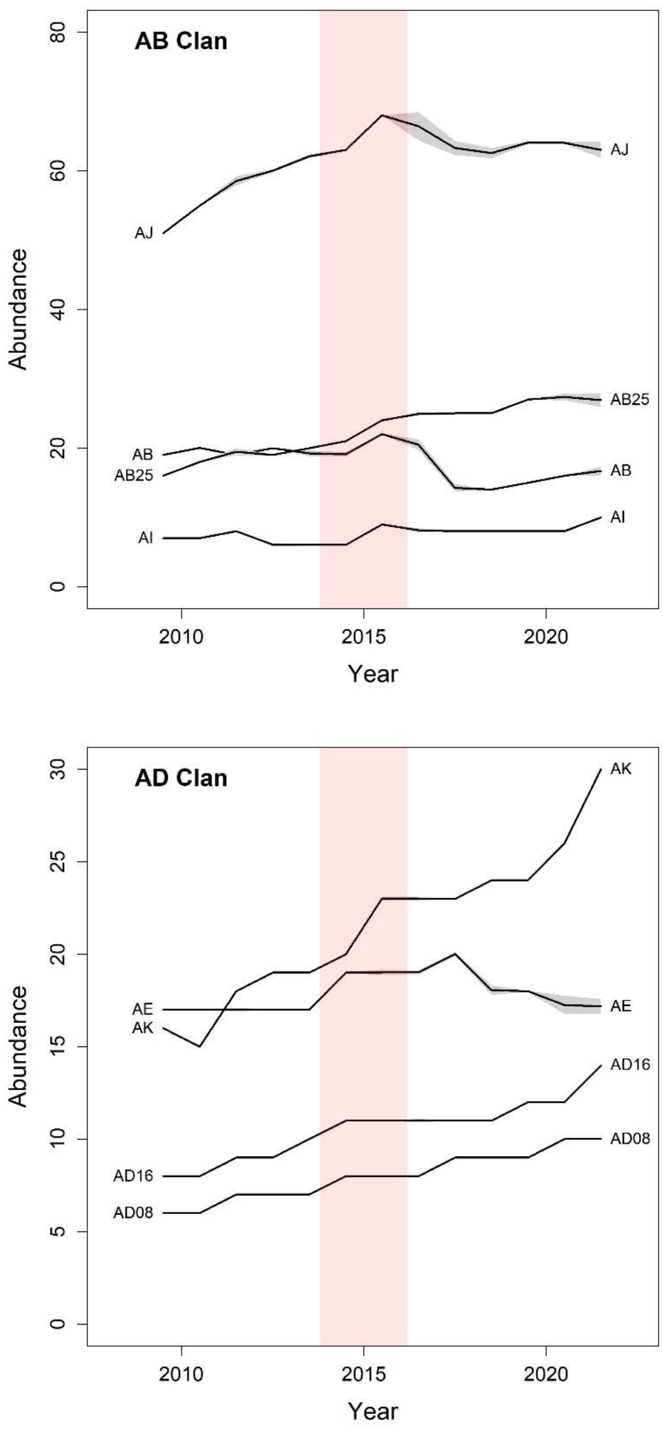

Figure 2: Abundance for eight pods of Resident killer whales that were photo-identified annually between 2009 and 2021 in Prince William Sound and the coastal waters around the Kenai Fjords. These comprise four pods from the acoustically and genetically similar AB Clan and four from AD Clan, with pod identifiers displayed as labels on the plots. Abundance was estimated for each year by fitting a Bayesian latent-state mark-recapture model to photo-identification data: uncertainty about if and when whales died is illustrated in the gray polygons showing the standard deviation of the Bayesian posterior distribution for each annual abundance estimate. Solid lines represent the time series of posterior means and pink shading indicates the timing of the marine heatwave in the Gulf of Alaska from 2014-2016.

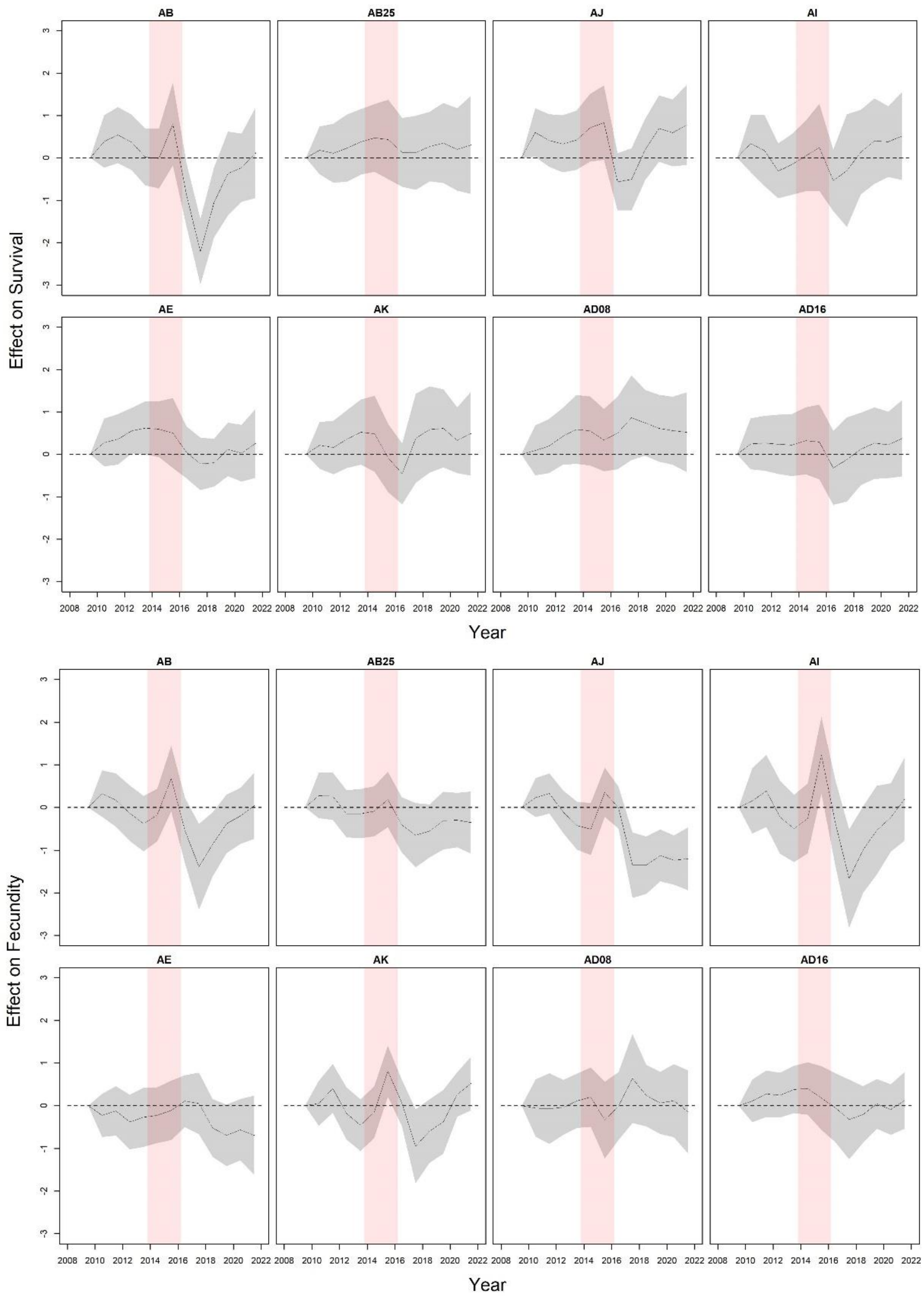

Figure 3: Annual departures from expected survival (top) and fecundity (bottom), plotted separately for eight pods of Resident killer whales. Gray polygons showing the standard deviation of the Bayesian posterior distribution each annual estimate, solid lines represent the time series of posterior means and pink shading indicates the timing of the marine heatwave in the Gulf of Alaska from 2014-2016.

Aerial photogrammetry to quantify killer whale responses to environmental change

In recent years the abundance, survival and fecundity of fish-eating Resident killer whales in the Gulf of Alaska declined following an intense and prolonged marine heatwave (Durban et al. in prep). This demonstrates the potential for the impact of climatic events to permeate up through the marine ecosystem to these top predators, and has emphasized the need to understand how increasing environmental variation will affect their recovery potential. However, killer whales live in stable populations and reproduce slowly, so assessing changes to population health and responses to environmental changes through demographic monitoring can take decades. In 2021 we therefore began to use aerial photogrammetry to provide more sensitive measurements of nutritional health.

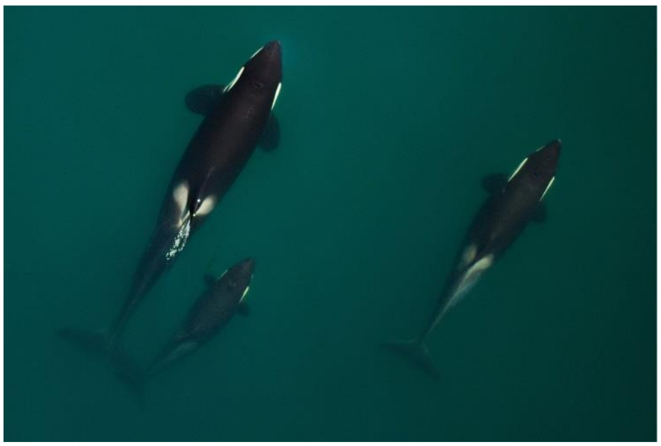

Figure 1: Aerial image taken by a drone at a non-invasive altitude of >100ft directly above Resident killer whales in Prince William Sound. Photogrammetry measurements from such images will quantify body condition and growth. More than 32,000 images were collected in 2022.

Using measurements from vertical photographs taken by non-invasive drones (Figure.1; e.g. Durban et al. 2021) we are assessing seasonal and interannual differences in the fatness of the whales, to understand short-term responses to changes in the food web that supports them (e.g. Stewart et al. 2021). Measurements of body lengths will allow an even longer decadal perspective on individual health (e.g. Groskreutz et al. 2019) by investigating if nutritionally-driven changes in the size of whales affects their reproductive success and survival. During our first full year of photogrammetry research in 2022 we collected aerial images for measurements of ~150 different Resident killer whales; photogrammetry analyses are underway.

References

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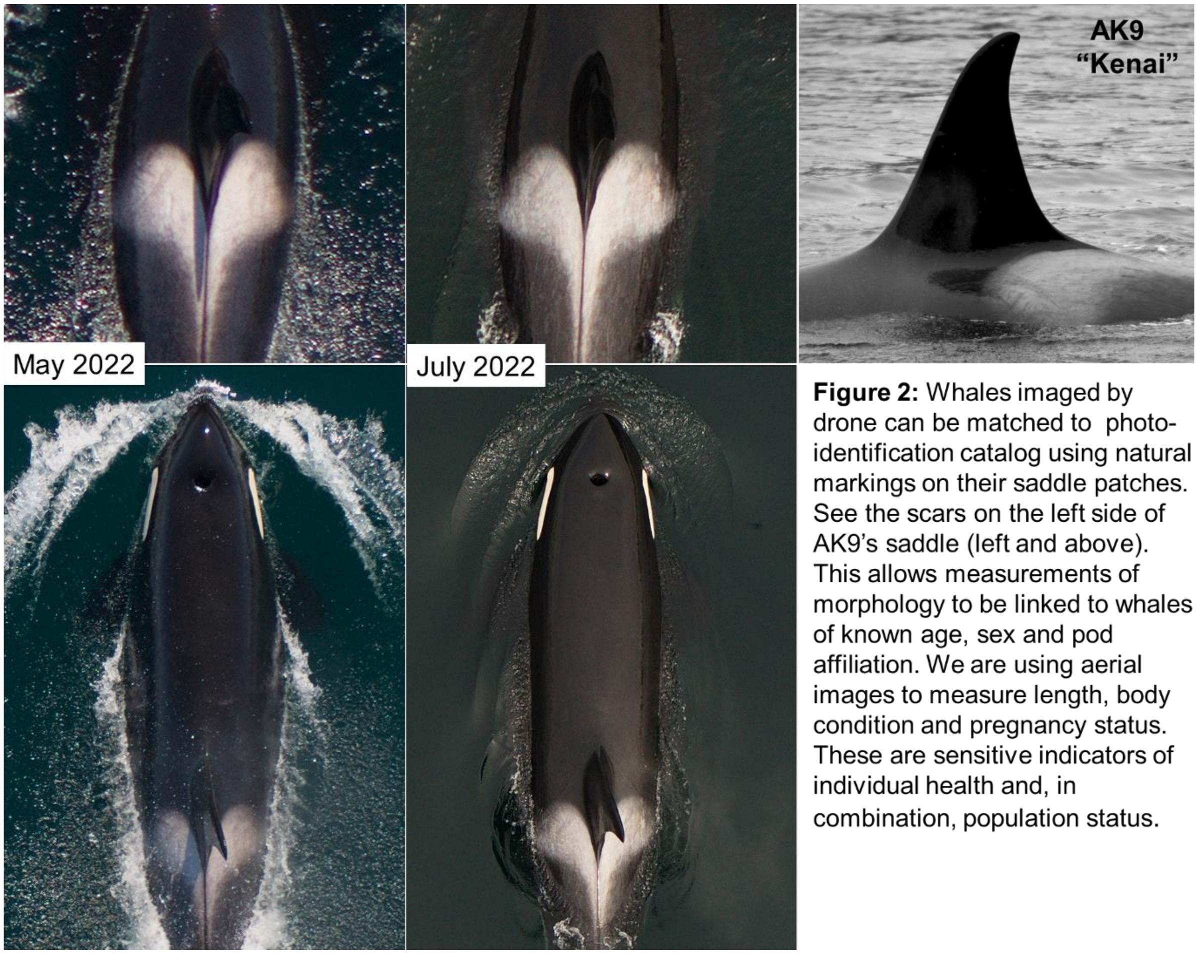

Figure 2: Whales imaged by drone can be matched to photo-identification catalog using natural markings on their saddle patches. See the scars on the left side of AK9’s saddle (left and above). This allows measurements of morphology to be linked to whales of known age, sex and pod affiliation. We are using aerial images to measure length, body condition and pregnancy status. These are sensitive indicators of individual health and, in combination, population status.

Passive acoustic monitoring of killer whales reveals year-round distribution and residency patterns in the Gulf of Alaska

In a recent publication (Myers at al. 2021), we provided the first description of the year-round distribution of killer whales in the northern Gulf of Alaska using passive acoustic monitoring. We further described the daily acoustic residency patterns of three killer whale populations (southern Alaska Residents, Gulf of Alaska Transients, and AT1 Transients). The highest year-round acoustic presence occurred in Montague Strait, while logistic regressions showed strong seasonal patterns in Hinchinbrook Entrance and Resurrection Bay. Daily acoustic residency times for the southern Alaska Residents paralleled seasonal distribution patterns. The majority of Gulf of Alaska Transient detections occurred in Hinchinbrook Entrance in spring. The depleted AT1 Transient killer whale population was most often identified in Montague Strait. Passive acoustic monitoring revealed that both Resident and Transient killer whales used these areas much more extensively than previously known and provided novel insights into high use locations and times for each population. These results may be driven by seasonal foraging opportunities and social factors and have management implications for this protected species.

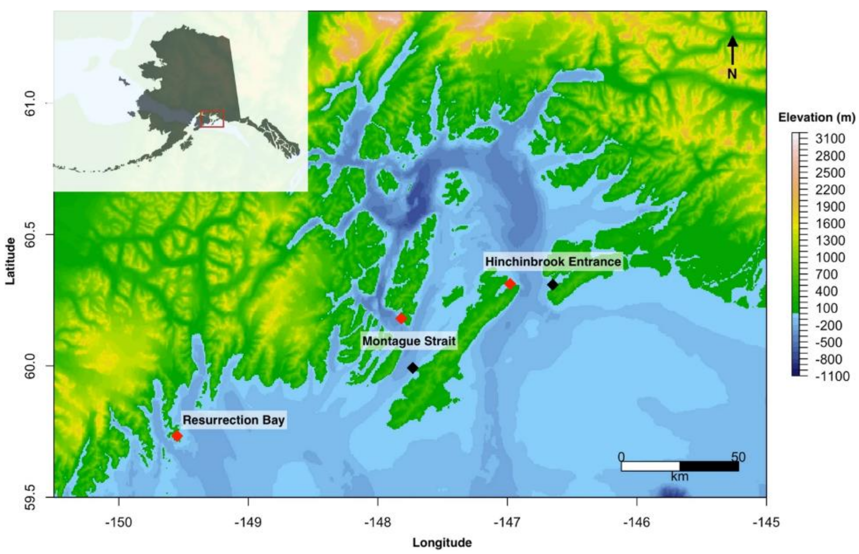

Figure 1: Map of hydrophone locations in the northern Gulf of Alaska. Red points indicate final hydrophone sites in Resurrection Bay, Montague Strait (Little Bay), and Hinchinbrook Entrance (Zaikof Bay). Black points indicate initial hydrophone sites in Montague Strait (Hanning Bay) and Hinchinbrook Entrance (Port Etches). Inset map shows location of study area in the northern Gulf of Alaska.

References

Myers, H.J., Olsen, D.W., Matkin, C.O., Horstmann, L.A. and Konar, B., 2021. Passive acoustic monitoring of killer whales (Orcinus orca) reveals year-round distribution and residency patterns in the Gulf of Alaska. *Scientific Reports*, *11*(1), pp.1-14. https://doi.org/10.1038/s41598-021-99668-0

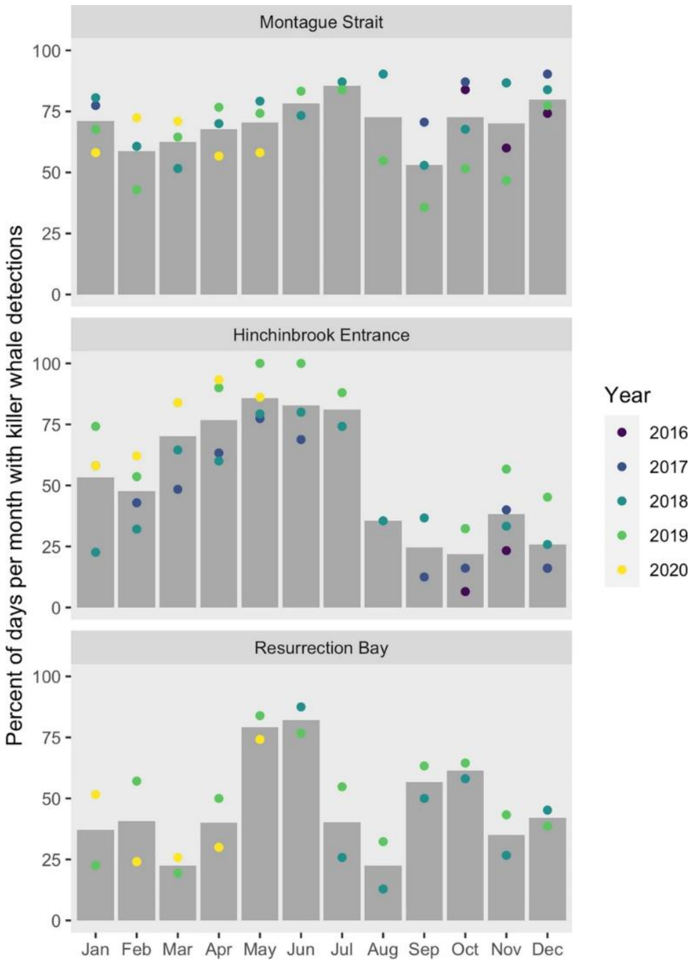

Figure 2: Percent of days per month that killer whales were detected at Montague Strait, Hinchinbrook Entrance, and Resurrection Bay, Gulf of Alaska, October 2016 to May 2020. Columns represent the average across years at each location, colored points represent values for each year recordings were available.

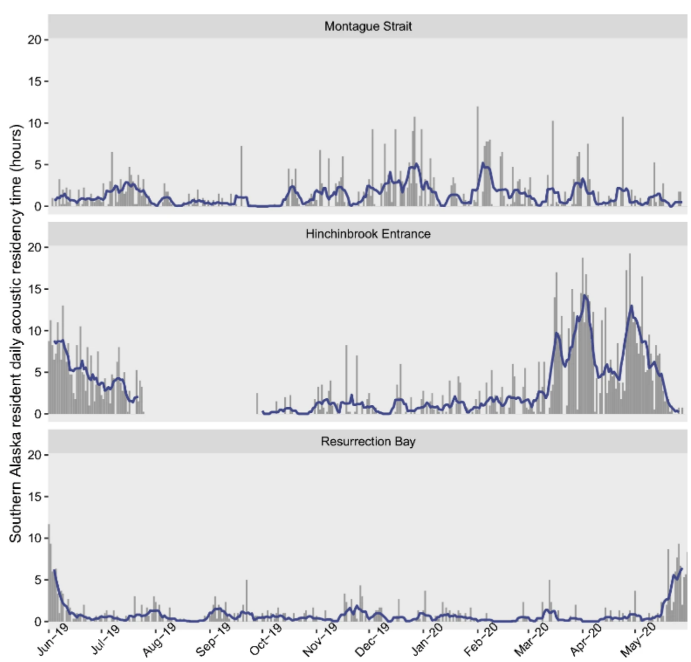

Figure 3: Hours per day that southern Alaska resident killer whales were detected in Montague Strait, Hinchinbrook Entrance, and Resurrection Bay, Gulf of Alaska, June 2019 to May 2020. Gray bars represent daily hours with detections, blue line is a weekly rolling average. No data were available at Hinchinbrook Entrance from July 26th–September 27th, 2019 and May 30th–31st, 2020 and at Montague Strait from September 25th–26th, 2019.

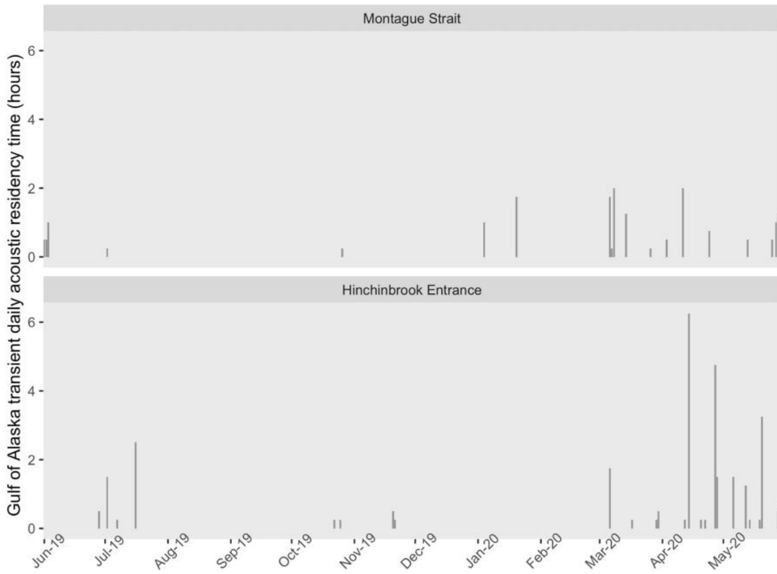

Figure 4: Hours per day with Gulf of Alaska transient killer whale detections in Montague Strait and Hinchinbrook Entrance, Gulf of Alaska, June 2019 to May 2020.

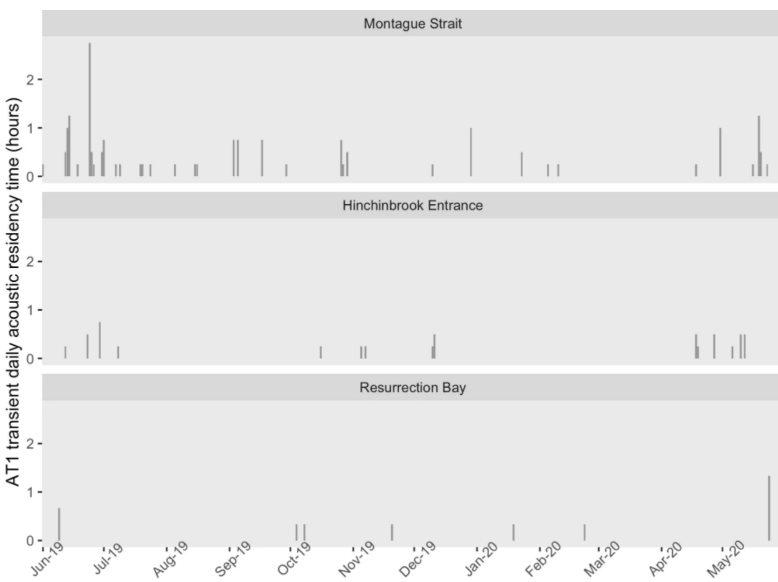

Figure 5: Hours per day with AT1 transient killer whale detections at Montague Strait, Hinchinbrook Entrance, and Resurrection Bay, Gulf of Alaska, June 2019 to May 2020.

Genetic prey barcodes elucidate the diet of Alaska Resident killer whales from fecal samples

Characterizing the diet of fish-eating Resident killer whales is important for understanding their role in Alaska marine ecosystems, tracking population health, and informing conservation and management efforts. Collection of scale samples and prey remains from surface waters can be very informative for discrete foraging events, however, surface samples of prey scales and tissues likely underrepresent prey consumed at depth. Generating prey DNA sequences from fecal samples (or fecal prey metabarcoding) is an effective tool for elucidating the diet of top predators and has been successfully applied to a wide range of terrestrial and aquatic species, including killer whales in the Pacific Northwest. The North Gulf Oceanic Society has been collecting fecal samples from Gulf of Alaska killer whales since 2016 and partnering with molecular geneticists at Northwest Fisheries Science Center (NOAA Fisheries) to apply previously optimized molecular techniques to genetically identify prey species consumed by Alaska killer whales. Total genomic DNA from was successfully extracted and analyzed from 86 killer whale fecal samples collected between 2016 and 2021 in the Gulf of Alaska including the waters of Prince William Sound and the Kenai Fjords. Using previously published (Hanson et al 2021; Ford et al 2016) 16S prey metabarcoding we characterized the relative composition of prey species in each sample and explored seasonal shifts in prey preference. Nuclear SNPs were used to genotype individual fecal samples to identify unique killer whales and can be used to explore the stability of prey preferences over time and across social groups or pods.

Six fish species were found in proportions exceeding 1% of the sequencing reads in at least 4 killer whale fecal samples (Figure 1): Chinook salmon (*Oncorhynchus tshawytscha*, hereafter "Chinook"), chum salmon (*Oncorhynchus keta*, "chum"), coho salmon (*Oncorhynchus kisutch*, "coho"), Pacific halibut (*Hippoglossus stenolepis*, "halibut"), arrowtooth flounder (*Atheresthes stomas*, "arrowtooth"), and sablefish (*Anoplopoma fimbria*, "sablefish"). Chinook made up the greatest proportion of the diet, proportionally representing 58% of sequences from all fecal samples, and comprised greater than 50% of the sample in ~ 43% of samples collected. Chum had the second highest prevalence, proportionally representing 33% of the sequences from all fecal samples, and comprising greater than 50% of the sample in ~39% of samples collected. Genetic data on Alaska resident killer whale prey preferences provides valuable insight into key prey species for this top predator and complement and support ongoing diet assessments based on the analysis of prey remains collected from surface waters near foraging killer whales, and provide an important reference for other eastern North Pacific resident killer whale populations.

References

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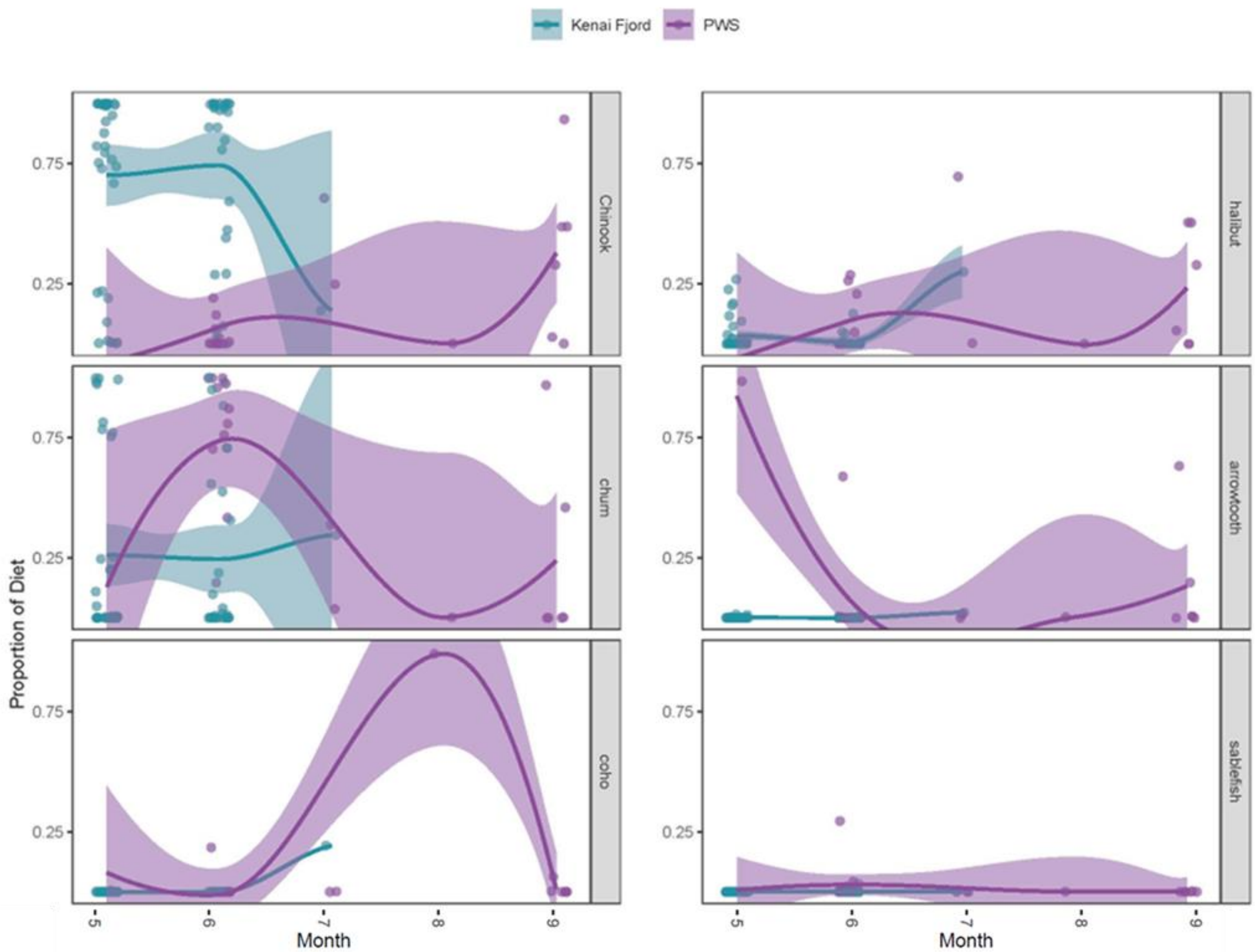

Figure 1. Temporal and geographic patterns in the six top prey species identified from fecal samples collected 2016 – 2022 from Alaska Resident killer whales.

Proposed reduced budget

Following the advice of the Trustee Council from the January 2021 meeting, we recognize the need to seek alternative funding to support our killer whale monitoring project in the long-term, and we have been successful in beginning this transition by securing partial funding support from the U.S. Marine Mammal Commission and a donation from a Seward-based ecotourism company. However, we also appreciate the understanding of the TC that it will take time to implement a full transition away from EVOS funding, and we are grateful for their continued support for our extremely successful year of data collection in FY22.

Recognizing that it will take time to transition our funding support, and to be able to deliver on the core monitoring products proposed for the first half (FY22-26) of our previous FY22-31 proposal, we would like to request that the TC consider funding our project for a further three years (FY23, FY24 and FY25) at a greatly reduced rate. The reduced rate is possible because we have been able to secure some funding from elsewhere. The reduced duration will allow two further years of data collection in FY23 and FY24, followed by an analysis and synthesis year in FY25 to allow us to meet analysis goals to deliver on the monitoring products for this period detailed in our previous proposal.

Summary of the reduced budget we are proposing for the five-year period FY22-26. Including costs already granted for FY2022, the newly proposed five-year total for FY22-26 is $598,661, representing 52% (or a 48% reduction) of the 5-yr proposal presented previously in 2021.

	FY22	FY23	FY24	FY25	FY26	5-YR Total
Reduced	213,302	140,163	145,439	99,757	0	598,661
Previous	213,302	233,325	238,601	215,221	258,804	1,159,253