Exxon Valdez **Oil Spill Trustee Council**

Long-Term Research and Monitoring, Mariculture, Education and Outreach

Annual Project Reporting Form

Project Number: 22120114-G

Project Title: Oceanographic Conditions in PWS

Principal Investigator(s): Robert W. Campbell, Prince William Sound Science Center

Reporting Period: February 1, 2022 – January 31, 2023

Submission Date (Due March 1 immediately following the reporting period): March 1, 2023

Project Website: https://gulfwatchalaska.org/

Please check all the boxes that apply to the current reporting period.

☒ **Project progress is on schedule.**

☐ **Project progress is delayed.**

☐ **Budget reallocation request.**

☐ **Personnel changes.**

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1. Summary of Work Performed:

The planned surveys of Prince William Sound (PWS) were conducted during the reporting period (Table 1), and all 12 standard stations were occupied. All conductivity and temperature at depth (CTD) data collected to date have been processed, and seasonally detrended anomalies of temperature at selected depths in central PWS are shown in Fig. 1. Temperatures in central PWS have mostly been above average since late 2013, as has been observed elsewhere in the Gulf of Alaska (see Seward Line and GAK1 projects), and late 2013 to 2016 has been labelled a basin scale marine heatwave (Gentemann et al. 2017). Following a weak cooling trend into early 2018 and a brief period of negative anomalies, anomalies have again trended warmer than average, which corresponds to basin-wide increases in sea surface temperature observed in late 2018 and 2019. Near-surface temperature anomalies in 2019 exceeded those observed during the 2013-2016 marine heatwave and appear to be the result of a similar mechanism: a persistent atmospheric ridge (Bond et al. 2015, Amaya et al. 2020). In 2013-2014 the ridge disrupted winter storm tracks and lead to reduced mixing of heat out of the surface layer during winter; in 2020 a similar ridge led to over a month of calm, sunny weather in July-August that led to enhanced solar heat flux to the surface layer and very high surface layer temperatures.

Anomalies again trended towards much warmer than average in early 2022 but returned to near to climatology in the latter portion of the year.

Table 1. Status of deliverables and milestones for the Prince William Sound (PWS) Oceanographic project.

Deliverable/Milestone	Status
PWS Survey	Conducted March 6 – 10 2022
Deploy profiling mooring	Deployed 30 March 2022
Service mooring	Conducted 4 April 2022
PWS Survey	Conducted 20-25 April 2022
Service Mooring	Conducted 5 May 2022
PWS Survey/ Service mooring	Conducted 8-10 June 2022
Service mooring	Conducted 6 July 2022
PWS Survey	Conducted 14-15 Sept. 2022
PWS Survey	Conducted 31 Oct – 11 Nov. 2022
CTD Data processed	Completed December 2022
Chlorophyll- samples processed	To be completed in Q1 2023
Plankton samples enumerated	Ongoing

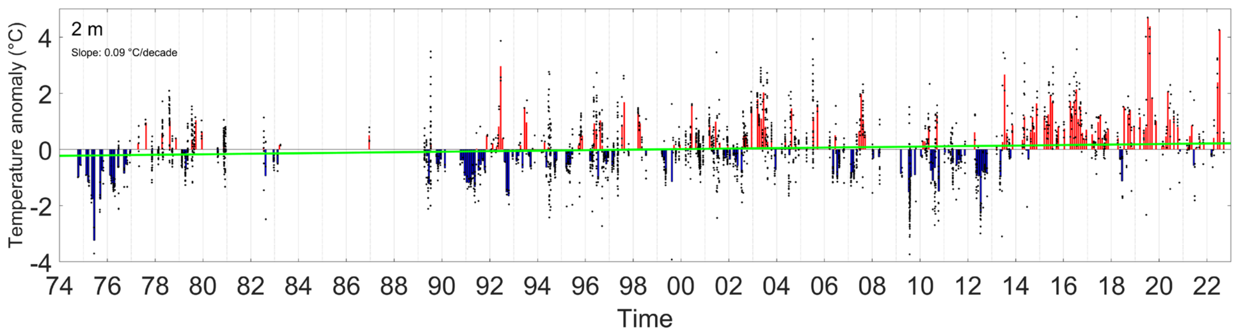

Figure 1. Biweekly near surface temperature anomalies in central Prince William Sound. Anomalies were calculated as the residual to a second order cosine curve fit to all years data (to remove seasonality: Campbell, 2018). Black points are observations, bars are biweekly averages, and the green line indicates the linear trend. Slope was significantly different from zero (p<0.05).

Plankton and chlorophyll-a samples were collected from all stations with no incidents. Sample processing is catching up following delays caused by the COVID-19 pandemic and the departure of Caitlin McKinstry, the technician who processed those samples. A new technician, Jessica Pretty, joined the Science Center in March 2022, she spent several weeks at UAF learning the common plankton taxa in the Hopcroft lab, and has been catching up on the backlog and the 2021 data has been uploaded to the workspace ahead of the deadline.

Analysis of the 2010 to 2021 samples shows a shift in zooplankton taxa in PWS during the marine heatwave years (Fig. 2). When copepod species are split into the “warm” and “cool” water species assemblages used by Fisher et al. (2017), it is apparent that although changes in overall zooplankton abundance have been relatively small (note the different axes scaling in the panels of Fig. 2), abundances of “warm” water copepod species increased, while that of the canonical “cool” water subarctic copepod species decreased during heat wave years. A shift back towards increased cool water species and decreased warm water species occurred in 2018, but may have switched again in late 2019 following the second heat wave; cool water species have become much less common recently. A lag of 1-2 years between the onset of warmer conditions (Fig. 1) and changes in the zooplankton composition (Fig. 2) is apparent. The lag can be attributable to both transport (i.e., the advection of taxa more common to the California Current to the north), and/or enhanced productivity of warm-preferring taxa in place. No studies showing changes in transport during the marine heatwave years have been published as yet, and the canonical warm water species used here have been observed in the PWS region previously (e.g., Cooney and Coyle 1985), which supports the latter hypothesis. A detailed analysis of the changes in species composition is outlined in McKinstry and Campbell (2018).

The profiling mooring was deployed March 30, 2022, and profiled for several days before malfunctioning; it was serviced in early April when the weather allowed. The profiler malfunctioned again late August, was serviced in September, and did a number of profiles into October before malfunctioning a third time. The malfunctions appear to have been related to the profiler battery. Replacing the batteries is not budgeted (~$40K each), and we are working with engineers at Georgia Tech to develop a less expensive, more user-serviceable battery.

The 2022 time series from the profiler shows the annual cycle of surface warming, with the onset of thermal and salinity stratification in spring/early summer and the breakdown of stability in autumn (Fig. 3). The water column was isothermal with elevated nitrate near-surface when the profiler was deployed, which was rapidly drawn down in mid-April as the spring bloom progressed. Following the spring bloom, productivity was centered on the nitricline, which has been observed in prior years. Temperature anomalies were strongly positive near-surface in spring-summer, and slightly negative at depths below ~15-20m. Deep waters of PWS are warming (Fig. 1), and the negative temperature anomaly is likely a manifestation of a surface mixed layer that is shallower than the climatology (deep waters tend to be cooler than surface waters).

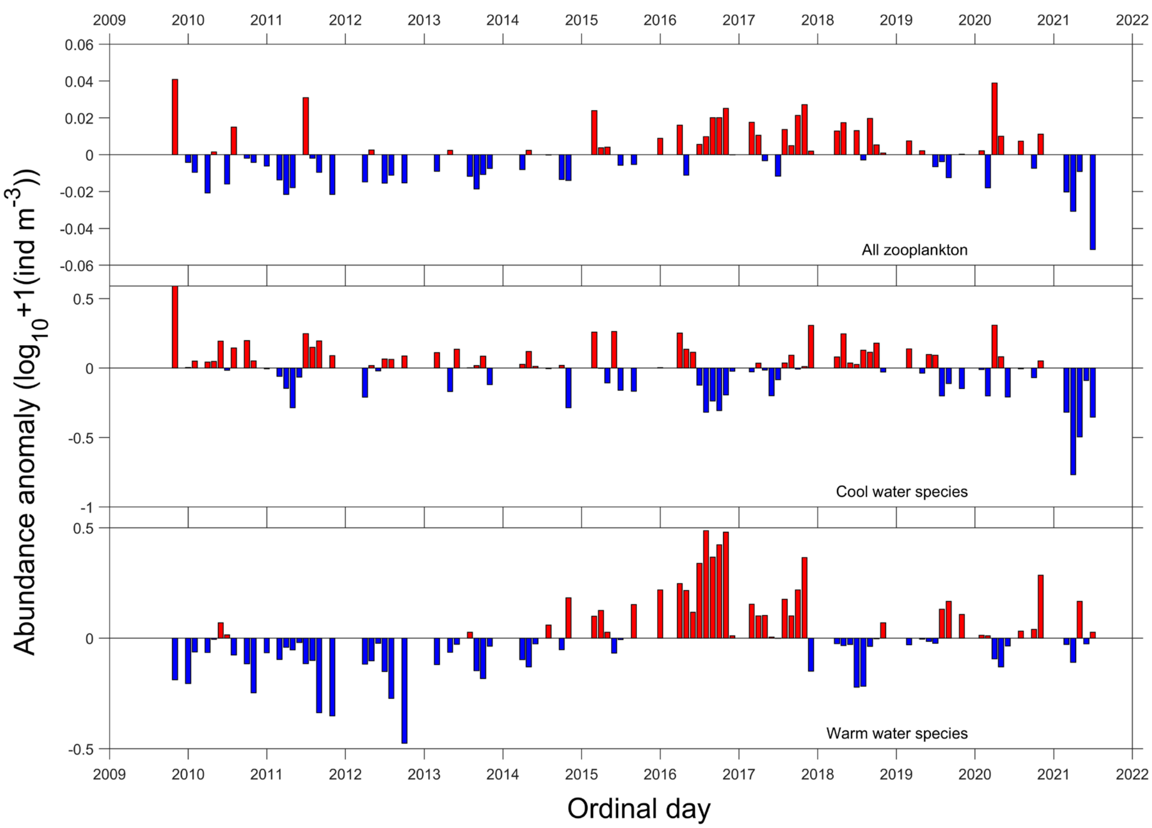

Figure 2: Time series of zooplankton anomalies in Prince William Sound, 2010-2021. Zooplankton were divided into "warm" and "cool" water copepod species per Peterson et al. (2017) and average anomalies calculated across groups per Fisher et al. (2015). Warm water species were Calanus pacificus, Clausocalanus sp., Corycaeus anglicus, Ctenocalanus vanus, Mesocalanus tenuicornis and Paracalanus parvus. Cool water species were Acartia longiremis, Calanus marshallae, Oithona similus, and Pseudocalanus sp. Abundances were log10+1 transformed prior to calculating anomalies. Note that the scaling of the ordinate varies among panels.

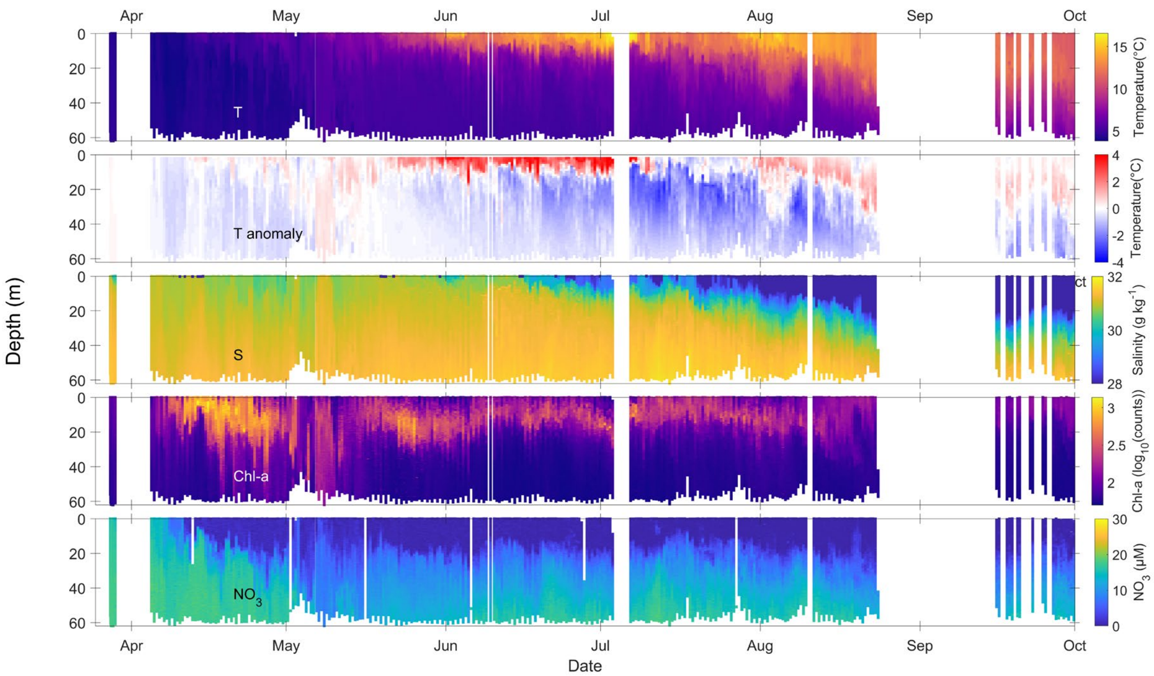

Figure 3. Time series of observations made by the Prince William Sound autonomous profiler in 2022. Top panel: temperature (°C). Second panel: Temperature anomaly (°C). Temperature anomalies were calculated with the method of Campbell (2018) used in Fig. 1. Third panel: Salinity (TEOS-10). Fourth panel: Chlorophyll-a fluorescence. Chlorophyll is presented as log10 transformed digital counts (counts are linearly proportional to chlorophyll-a concentration). Fifth panel: Nitrate concentration (µM) from a Satlantic SUNA.

A plankton camera was developed and installed on the profiler in 2016, with funding from the North Pacific Research Board. A training set of ~20,000 manually identified images in 43 different taxa and visually distinctive groups has been produced, and used to train a version of the Google-developed Inception v3 convolutional neural net (CNN) merged with a second neural network to include measurements of size and texture. CNNs necessarily discard size information, and we have found that including size information allows discrimination of similar taxa (e.g. calanoid copepods of different size). Application of a probability filtering technique that assesses the relative confidence of the classifier returns accuracies >90% for numerous groups, with most confusion concentrated in the less informative classes (catchall groups like "large copepods" versus specific species), and in smaller classes that tend to be less sharp (Campbell et al., 2020).

The classifier is now being applied to the full image set, and concordance with samples taken with a 202 µm mesh plankton net at approximately the same time and depth range is show for copepod groups in Fig. 4, and gelatinous taxa in Fig. 5. These results highlight the difference between the two sampling methods: the camera observes fewer copepods than seen in the net samples, which may reflect avoidance of the camera frame, which has a smaller opening (15 cm) than the net (60 cm). Copepods are very sensitive to tactile stimulation and the pressure wave produced by the profiler and camera can elicit escape reactions (the camera has captured numerous images of copepods exhibiting an escape response). The camera appears to be more effective than the net at enumerating fragile taxa, such as Cnidarians, which are damaged or destroyed by net sampling. Several of the gelatinous taxa (*Beroe* and *Bollinopsis* ctenophores, and Siphonophores) have never been collected by the net at the profiler site and have only been observed by the camera.

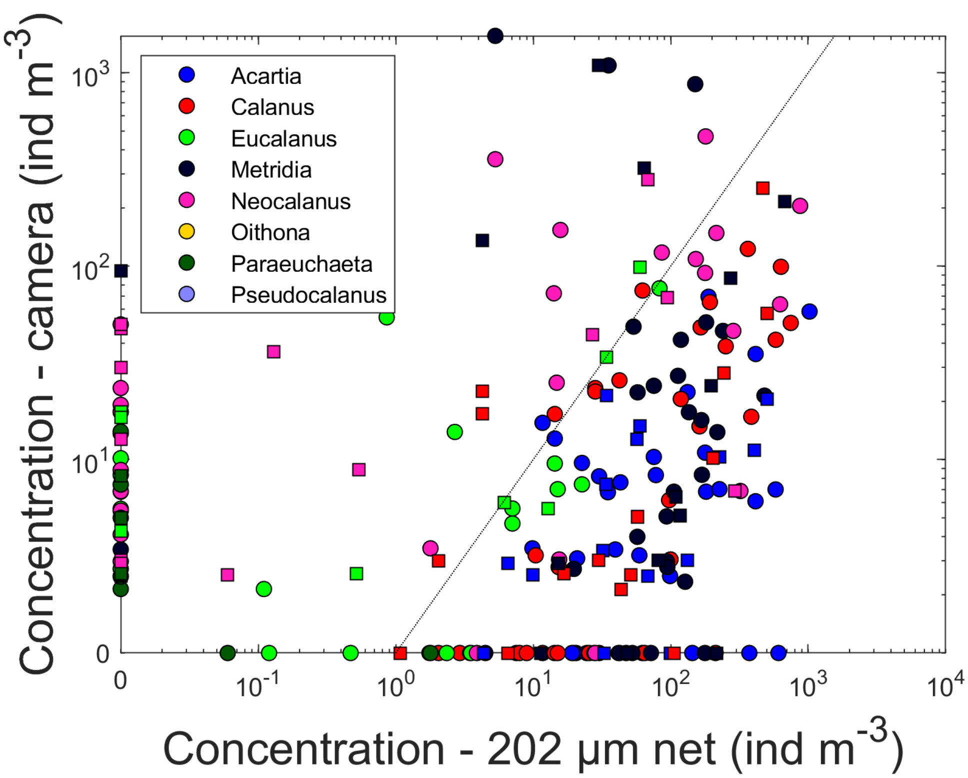

Figure 4. Comparison of abundance estimates for copepods derived from the plankton camera aboard the Prince William Sound Profiler (ordinate) and a 202 µm plankton net. The dashed line indicates the 1:1 line. Plankton tows were done after profiler service visits, and the tow was done from 0-60 m (the depth that the profiler samples), and as close in time to a profile as possible (usually <1 hour).

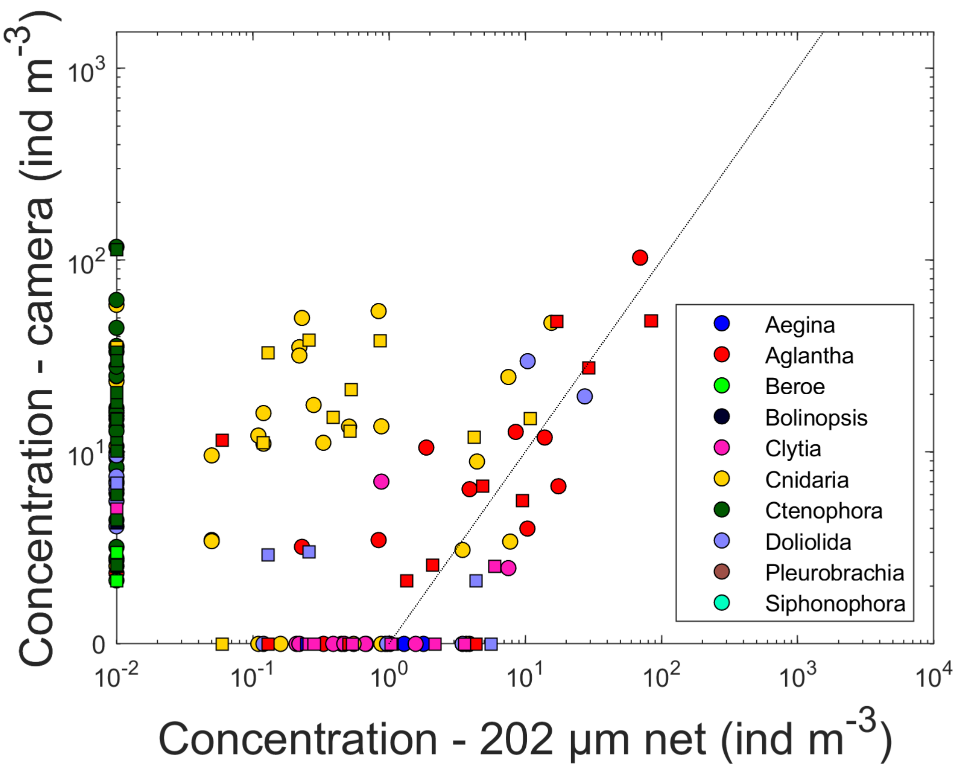

Figure 5. Comparison of abundance estimates for gelatinous tax derived from the plankton camera aboard the Prince William Sound Profiler (ordinate) and a 202 µm plankton net. The dashed line indicates the 1:1 line. Plankton tows were done after profiler service visits, and the tow was done from 0-60 m (the depth that the profiler samples), and as close in time to a profile as possible (usually <1 hour). Note that the axes scaling is the same between Figs. 4 and 5.

2. Products:

<u>*Peer-reviewed publications:*</u>

Du, X., R. W. Campbell, and S. Kibler. 2022. Seasonal Changes of Microphytoplankton Community in Prince William Sound, Alaska in 2019. Estuaries and Coasts. [doi: 10.1007/s12237-022-01144-z](doi: 10.1007/s12237-022-01144-z).

Danielson, S. L., T. D. Hennon, D. H. Monson, R. M. Suryan, R. W. Campbell, S. J. Baird, K. Holderied, and T. J. Weingartner. 2022. Temperature variations in the northern Gulf of

Alaska across synoptic to century-long time scales. Deep Sea Research II 203 doi: 10.1016/j.dsr2.2022.105155.

Dias, B. S., D. W. McGowan, R. W. Campbell, and T. A. Branch. 2022. Influence of environmental and population factors on Prince William Sound herring spawning phenology. Marine Ecology Progress Series 696:103-117. doi: 10.3354/meps14133.

McKinstry, C.A.E., R. W. Campbell, and K. Holderied. 2022. Influence of the 2014-2016 marine heatwave on seasonal zooplankton community structure and abundance in the lower Cook Inlet, Alaska. Deep Sea Research II 195 doi: 10.1016/j.dsr2.2021.105012.

Reports:

Campbell, R. W. 2022. Monitoring the Oceanographic Conditions of Prince William Sound. *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 21120114-G), *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Popular articles:

Campbell, R. 2022. Are you ready for your close-up? Counting plankton with cameras. Delta Sound Connections 2022-2023 https://pwssc.org/wp-content/uploads/2022/06/DSC-2022-WEB.pdf.

McKinstry, C. 2022. Warm waters have impact on tiniest Cook Inlet residents. Delta Sound Connections 2022-2023 https://pwssc.org/wp-content/uploads/2022/06/DSC-2022-WEB.pdf.

Conferences and workshops:

Campbell, R. W. 2022. The Prince William Sound plankton camera: A profiling in situ observatory of plankton and particulates. PICES Annual Meeting, Busan, South Korea.

Campbell, R.W. 2023. High Frequency Observations Of Plankton Distributions From The Prince William Sound Plankton Camera. Alaska Marine Science Symposium, online.

Cypher, A., K. Hoffman, G. Eckert, J. Decker, J. Whissel, R. Campbell, Q. Fong, M. Good, J. Hollarsmith, A. Kelley, B. Konar, C. Long, A. Pinchuk, M. Rehberg, A. Schaefer, S. Umanzor, and R. Bochenek. 2023. Sustainable mariculture development for restoration and economic benefit in the EVOS spill area: An introduction to the ReCon. Alaska Marine Science Symposium, online.

Cypher, A., H. Statscewich, R. Campbell, S. Danielson, J. Eiler, and M. A. Bishop. 2023. Detection efficiency of an autonomous underwater glider-mounted acoustic receiver for acoustic tagged Pacific herring. Alaska Marine Science Symposium, online.

Mearns, A., A. Campbell, D. Janka, B. Robinson, and S. Pegau. 2023. Volunteer-driven annual photography documents: The range of natural variability of rocky intertidal communities in western Prince William Sound. Alaska Marine Science Symposium, online.

Traiger, S., J. Bodkin, R. Campbell, H. Colletti, D. Esler, K. Holderied, C. McKinstry, D. Monson, H. Renner, B. Robinson, R. Suryan, and B. Weitzman. 2023. Does larval supply matter? Relating meroplankton variability with benthic invertebrate abundance in Prince William Sound. Alaska Marine Science Symposium, online.

Public presentations:

Campbell, R. W. 2023. Oceanography and plankton in Prince William Sound from a robotic observatory. Presentation to University of Alaska FRACAS faculty meeting. January 27.

Data and/or information products developed during the reporting period:

None.

Data sets and associated metadata:

Campbell. 2022. Environmental drivers: Oceanographic conditions in Prince William Sound. Gulf of Alaska Data Portal: https://gulf-of-alaska.portal.aoos.org/#metadata/fc5b0956-ef7c-49df-b261-c8e2713887fc/project.

Additional Products not listed above:

None.

3. Coordination and Collaboration:

The Alaska SeaLife Center or Prince William Sound Science Center

Dr. Campbell is an employee of the PWS Science Center and works closely with principal investigators (PIs; Cypher, Schaefer, Rand) on several other *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) projects.

EVOSTC Long-Term Research and Monitoring Projects

This project is part of the Environmental Drivers component of the Gulf Watch Alaska-Long-Term Research and Monitoring (GWA-LTRM) program. PI Campbell collaborates with other Environmental Drivers projects, is a co-PI on the herring-salmon interactions project (22220111-I), and coordinates with other Herring Research and Monitoring and Nearshore component projects.

EVOSTC Mariculture Projects

Dr. Campbell is a PI on the EVOSTC funded Mariculture ReCon project and is working with PIs Cypher, Shaefer, Rehberg and others on that project. We are sharing ship time and instruments among the projects. The data collected as part of this project will be used in Mariculture ReCon project as well.

EVOSTC Education and Outreach Projects

PI Campbell has participated in meetings with members of the CORaL network funded by EVOSTC to evaluate ways the programs can work together on outreach activities.

Individual EVOSTC Projects

In 2020 we began collecting samples to monitor for ocean acidification for project 20200127 (PI Hetrick). Samples are collected at two sites in PWS during every regular survey, one in in central PWS (representative of "open water" conditions) and one in Whale Bay (where acidification is expected to be enhanced by melting ice).

In addition, the project works with the Data Management program to publish data and metadata within required timeframes.

Trustee or Management Agencies

We generally endeavor to conduct a spring cruise around the time of herring spawning when the Alaska Department of Fish and Game is doing their surveys (contact: Jenni Morella, Alaska Department of Fish and Game, Cordova).

A North Pacific Research Board project (1801: Prevalence of Paralytic Shellfish Toxins in the Marine Food Webs of Prince William Sound and Kachemak Bay, Alaska) began in Sept. 2018. Dr. Xiuning Du (Oregon State University) was the lead PI and Campbell was a co-investigator. Phytoplankton and toxin samples have been collected for that project at all sites visited by this program. Campbell is also coordinating sampling efforts of larger taxa in PWS (shellfish, forage fish and salmon). Samples are being analyzed for saxitoxin by Dr. Steve Kibler (National Oceanic and Atmospheric Administration [NOAA], Beaufort Lab).

In addition, we contributed indicators to NOAA's Gulf of Alaska Ecosystem Status Report to the North Pacific Fisheries Management Council for 2020 2022 (e.g. see Ferriss and Zador 2022) on temperature trends in PWS.

The in situ camera and machine vision system developed for the profiler is being spun off into novel applications. In 2020 funding was obtained under the NOAA Saltonstall Kennedy program to develop low-cost and low-power camera systems to be deployed in small clear water streams to count salmon passage. The camera systems will include an onboard micro supercomputer that will be trained to identify different species of salmon as they pass and detect if they are moving up- or down-stream. The systems will be designed to transmit their counts of species-specific fish passage in near real-time through a cellular or satellite data connection. We have produced working prototype cameras, and have trained algorithms to successfully discriminate between pink and sockeye salmon. Development of the cameras will continue.

We have also found that the machine vision algorithms developed to identify the plankton images collected by the profiler (Campbell et al., 2020) show promise for aging salmon scales. A proposal to the North Pacific Research Board was funded in 2022 (project 2203, "Automation of sockeye scale age estimation"). We have digitized several thousand scales from the Copper River fishery and will compare ages estimated by five different human agers to that done by deep neural network classifiers.

Native and Local Communities

None.

4. Response to EVOSTC Review, Recommendations and Comments:

May 2021 EVOSTC Science Panel Comment: This proposal continues routine oceanographic surveys of PWS to extend ongoing time series of physical (temperature, salinity, turbidity), biogeochemical (nitrate, phosphate, silicate, dissolved oxygen) and biological (chlorophyll-a concentration, zooplankton abundance and composition) parameters in central PWS, at the entrances, and in four bays that were part of the EVOSTC-funded Sound Ecosystem Assessment project in the 1990s and the Herring Research and Monitoring project in the 2010s. Also, an autonomous profiling mooring will be deployed each year in central PWS that will conduct frequent (twice daily) profiles of the same physical, biogeochemical, and biological parameters as the surveys, plus a plankton camera mounted on the profiler that will capture images of zooplankton, large phytoplankton and other particles. This project also provides a platform for fall and winter observations of seabird abundance (project 22120114-E).

As detailed in the annual report and this proposal, we note the value of these observations to document recent marine heatwaves and their impacts on zooplankton community composition, as well as a decades-long decline in productivity of PWS. This project has been meeting its objectives consistently, with little impact of the Covid-19 shutdown. This project has also been productive in terms of publications and presentations. In just the past year, the project resulted in three peer-reviewed journal articles, four EVOSTC reports, and one popular article. The proposed study design and analytical methods are sound and consistent with those employed to date. It is highly commendable that the camera and machine vision systems have led to value-added applications, such as salmon enumeration in clear-water streams. The machine vision system also has potential in aging of salmon scales. We also note that this is one of the most integrated projects, with 50% match with non-EVOSTC funds. At $2.8 M for 10 years (~$280 K per year), the project provides overall good value for the important data being collected.

<u>PI Response:</u> *I thank the Science Panel for their kind words, the many years of effort put into this project is now starting to pay dividends. The PWS Science Center has made a significant commitment to making this project possible, including the purchase and refit of our research vessel, and continuous upgrades to instruments, laboratory and other working facilities. We have been very successful in leveraging new proposals off of this project and will continue to look for new opportunities, there are several proposals in development at present. It is always difficult to predict how long it will take for those proposals to be successful, but I note that in the last five years of the project over $1.1 M of leveraged projects were funded by the North Pacific Research Board and NOAA.*

<u>May 2021 EVOSTC Science Panel Comment:</u> Finally, we offer the following comment regarding synthesis to all five oceanography projects: PWS oceanography, Cook Inlet oceanography, GAK1, Seward line, and CPR. Specifically, we recommend an integrative synthesis of all five oceanography projects to be included in the proposal(s). In addition to reporting project results separately for each area as proposed, there is opportunity for a region-wide synthesis that draws all results together for a broader perspective. For example, a synthesis might address connectivity of PWS and Cook Inlet to the northern GOA, predictability of Cook Inlet oceanography from PWS oceanography, and so on. We defer to the program managers and project PIs to determine the best approach to tackle this synthesis; one suggestion is to recruit some of the postdoctoral fellows proposed under the broader LTRM heading to address this region-wide synthesis of oceanographic conditions using already existing data.

<u>PI Response:</u> *Continued integration among all GWA projects, including Environmental Drivers, is a priority for the next 10 years of GWA-LTRM. For Environmental Drivers, the Danielson et al. (in review) paper provides examples of spatial and temporal scales of variability in near-*

surface ocean temperatures across the GOA from all sources within and various sources outside GWA. We will expand on these efforts on the physical environment by conducting similar analyses with sub-surface temperatures and salinity, which strongly link to nutrients. Additional integration steps will focus on similar analyses for phytoplankton and zooplankton, ultimately integrating the two approaches to propose mechanisms of change in species abundance and composition, onshore vs. offshore production, etc. Correct, the Environmental Drivers component will be using their three years of postdoc funding to support these efforts. Furthermore, Environmental Driver PIs will work with the GWA Synthesis and Modeling component over the next 10 years to highlight integrated analyses within work plans and annual reports.

Danielson, S.L., T.D. Hennon, D.H. Monson, R.M. Suryan, R.W. Campbell, S.J. Baird, K. Holderied, and T.J. Weingartner. in review. Marine temperature variations in the northern Gulf of Alaska across years of marine heatwaves and cold spells. Submitted to Deep-Sea Research II Special Issue.

<u>September 2021 EVOSTC Science Panel Comment:</u> This proposal collects important ongoing oceanographic observations in PWS. It also provides a platform for fall and winter observations of seabird abundance (project 22120114-E). These observations have documented recent marine heatwaves and their impacts on zooplankton community composition and has documented a decades-long decline in PWS productivity. This project has been achieving its objectives and has resulted in many publications and presentations. The proposed study design and analytical methods remain sound. The PI for this specific project is commended for the high level of collaboration with other LTRM components, other EVOS-funded projects, proposed new mariculture and E&O projects, and other entities.

In addition to comments on this specific proposal, in March we also offered a general comment to all five EVOS-funded oceanography projects asking for a plan to synthesize these into a comprehensive, integrated picture of oceanographic conditions across the northern Gulf of Alaska. The PIs for all five oceanographic projects provided the identical response to this request. We seek clarification specifically about how the PI of this project (22120114-G) has contributed to the present syntheses (Danielson et al. in review) and will contribute to these syntheses moving forward. The present generic response across all 5 proposals is not sufficient. What data would be used and how would they fit into the overall analysis and what will be the role of the PI in each case?

<u>PI Response:</u> *Because the Environmental Drivers group is very collaborative it seemed natural to draft a combined reply to the Science Panel, I apologize if the impression was that we were trying duck the comment- that was not our intent.*

I contributed data to the Danielson et al. 2022 (doi: 10.1016/j.dsr2.2022.105155) analysis, and participated in the drafting of the manuscript. I also contributed data and analysis to the other two synthesis manuscripts published during the FY17-22 project (Arimitsu et al. 2021 and Suryan et al. 2021) and have worked with the Herring Research and Monitoring program synthesis (Dias et al. 2022: doi: 10.3354/meps14133). I have tried to remain flexible when collaborating with others, some appreciate having some analysis done, others prefer to take the data and work with it themselves.

The Environmental Drivers postdoctoral position included in the proposal was intended to have a dedicated person working on synthesis supervised by Hopcroft. I know that that position was impacted by the overall delays in starting the project, and the uncertainty of the duration of the project given the Trustees' funding decisions. I will work with that person in whatever way is appropriate; all the data I have collected so far is available, and I will provide analysis as appropriate to the needs of the researcher.

5. Budget:

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

Budget Category:		Proposed FY 22	Proposed FY 23	Proposed FY 24	Proposed FY 25	Proposed FY 26	5- YR TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel		$165,796	$169,941	$174,189	$178,544	$183,008	$871,478	$34,843
Travel		$1,994	$2,044	$2,095	$2,147	$2,201	$10,481	$2,251
Contractual		$50,350	$51,610	$52,899	$54,222	$55,578	$264,659	$10,870
Commodities		$11,000	$11,275	$11,557	$11,845	$12,142	$57,819	$7,822
Equipment		$0	$0	$0	$0	$0	$0	$0
Indirect Costs Rate =	0%	$0	$0	$0	$0	$0	$0	$0
Indirect Waived								
SUBTOTAL		$229,140	$234,870	$240,740	$246,758	$252,929	$1,204,437	$55,786
General Administration (9% of subtotal)		$20,623	$21,138	$21,667	$22,208	$22,764	$108,399	N/A
PROJECT TOTAL		$249,762	$256,008	$262,407	$268,967	$275,692	$1,312,836	
Other Resources (In-Kind Funds)		$225,000	$225,000	$225,000	$225,000	$225,000	$1,125,000	

COMMENTS:
PWSSC waives the indirect cost on this proposal due to its administration of the overall proposal.

Spending is behind schedule in FY22 because of the delay in the release of funds from EVOSTC and issuance of the NOAA grant.

FY22-26

Project Number: 22120114-G
Project Title: PWS Oceanographic
Primary Investigator: Campbell

NON-TRUSTEE AGENCY SUMMARY PAGE

Spending is behind schedule in FY22 because of the delay in the release of funds from EVOSTC and the issuance of the NOAA grant.

6. Literature Cited

Amaya, D. J., A. J. Miller, S.-P. Xie, and Y. Kosaka. 2020. Physical drivers of the summer 2019 North Pacific marine heatwave. Nature Communications 11:1903. doi: 10.1038/s41467-020-15820-w.

Bond, N. A., M. F. Cronin, H. Freeland, and N. Mantua. 2015. Causes and impacts of the 2014 warm anomaly in the NE Pacific, Geophysical Research Letters 42:3414–3420 doi:10.1002/2015GL063306.

Campbell, R. W. 2018. Hydrographic trends in Prince William Sound, Alaska, 1960–2016. Deep Sea Research Part II doi: 10.1016/j.dsr2.2017.08.014.

Campbell, R. W., P. L. Roberts, and J. Jaffe. 2020. The Prince William Sound plankton camera: A profiling in situ observatory of plankton and particulates. ICES Journal of Marine Science doi:10.1093/icesjms/fsaa029.

Cooney, R. T., and K. O. Coyle. 1985. The occurrence of the subtropical copepod, *Mesocalanus tenuicornis*, in Columbia Bay, Prince William Sound, Alaska. Crustaceana 49:310-313.

Ferriss, B. and S. E. Zador (editors). 2022. Ecosystem Status Report 2022. North Pacific Fishery Management Council. https://apps-afsc.fisheries.noaa.gov/REFM/docs/2022/GOAecosys.pdf.

Fisher, J. L., W. T. Peterson, and R. R. Rykaczewski. 2015. The impact of El Nino events on the pelagic food chain in the northern California Current. Global Change Biology 21:4401-4414. doi: 10.1111/gcb.13054.

Gentemann, C. L., M. R. Fewings, and M. Garcia-Reyes. 2017. Satellite sea surface temperatures along the West Coast of the United States during the 2014–2016 northeast Pacific marine heat wave. Geophysical Research Letters Doi: 10.1002/2016GL071039.

McKinstry, C. A. E., and R. W. Campbell. 2018. Seasonal variation of zooplankton abundance and community structure in Prince William Sound, Alaska, 2009–2016. Deep Sea Research Part II doi: 10.1016/j.dsr2.2017.08.016.

Peterson, W. T., J. L. Fisher, P. T. Strub, X. Du, C. Risien, J. Peterson, and C. T. Shaw. 2017. The pelagic ecosystem in the Northern California Current off Oregon during the 2014–2016 warm anomalies within the context of the past 20 years. Journal of Geophysical Research Oceans 122:7267–7290 doi:10.1002/2017JC012952.

Swain, D. L. 2015. A tale of two California droughts: Lessons amidst record warmth and dryness in a region of complex physical and human geography. Geophysical Research Letters doi: 10.1002/2015GL066628.