ATTACHMENT B. Annual Project Report Form (Revised 11.21.19)

1. Project Number:

20120114-G

2. Project Title:

Monitoring the Oceanographic Conditions of Prince William Sound

3. Principal Investigator(s) Names:

Robert W. Campbell, Prince William Sound Science Center

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 planned surveys of Prince William Sound (PWS) were conducted during the reporting period (Table 1), and all 12 standard stations were occupied; the second cruise of the year was delayed briefly by the state COVID-19 shutdown in March/April and was done at the end of April. 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 been above average since late 2013, as has been observed elsewhere in the Gulf of Alaska (see Seward Line, project 20120114-L, and GAK1, project 20120114-I, reports), 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.

Table 1: Status of project milestones for FY20.

Deliverable/Milestone	Status
PWS Survey	Conducted 27 Feb – 1 March 2020
Deploy profiling mooring	Deployed 19 April 2020
PWS Survey	Conducted 26-28 April 2020
Service mooring	Conducted 20 May 2020
Service mooring	Conducted 4 June 2020
PWS Survey	Conducted 18-20 June 2020
Service mooring	Conducted 30 June 2020
PWS Survey	Conducted 12-13 August 2020
Service mooring	Conducted 12 August 2020
PWS Survey	Conducted 10-11 October 2020
Recover profiler	Conducted 22 October 2020
PWS Survey	Conducted 3-12 November 2020
CTD Data processed	Completed December 2020
Chlorophyll- samples processed	To be completed in Q1 2020
Plankton samples enumerated	Ongoing (this project and 20120114-J)

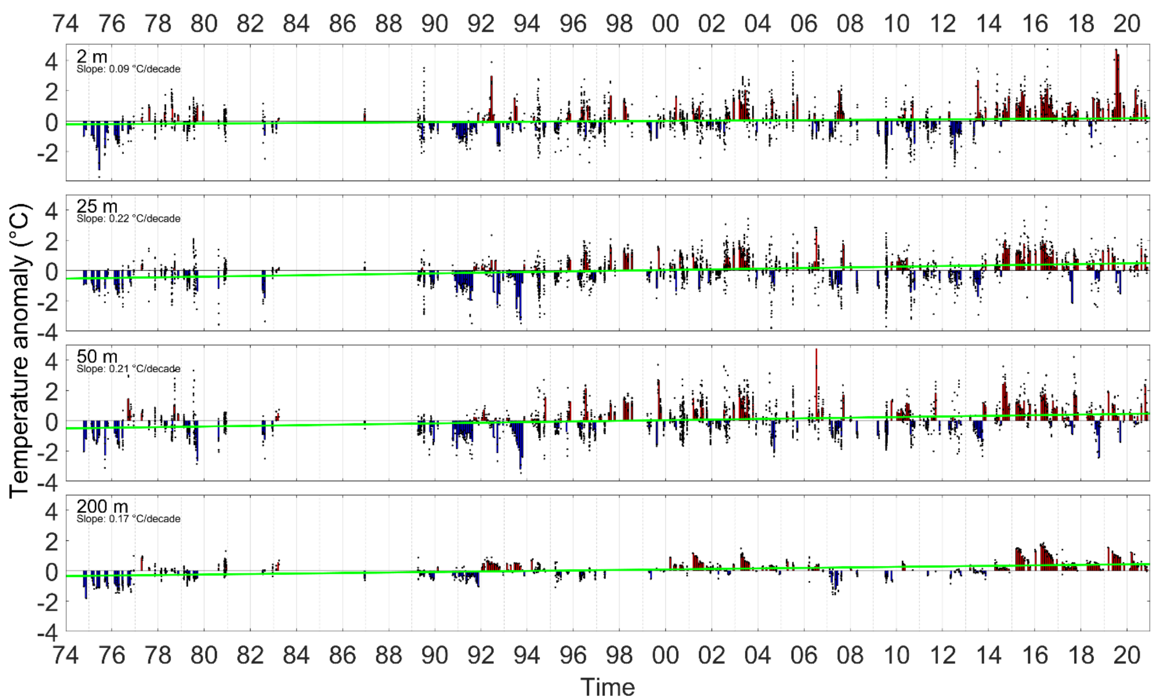

Figure 1. Temperature anomalies at four selected depths in central Prince William Sound. Anomalies were calculated as the residual to a second order cosine curve fit to all years data (to remove seasonality: Campbell 2018). Black points are observations, bars are biweekly averages, and the green line indicates the linear trend. All slopes were significantly different from zero ($p<0.05$).

Plankton and chlorophyll-a samples were collected from all stations with no incidents. Sample processing is behind schedule because there were several weeks of lost work caused by the COVID-19 shutdown in spring 2020 and ongoing protocols have reduced the occupancy levels allowed in the laboratory (so that staff will not overlap in a confined space). Caitlin McKinstry, the technician who enumerates zooplankton and does the chlorophyll analysis, was able spend some of that time working on a manuscript describing the zooplankton in lower Cook Inlet collected by the Oceanography of lower Cook Inlet and Kachemak Bay project (20120114-J) with principal investigators (PIs) Holderied and Baird, using the methods developed in McKinstry and Campbell (2018).

Analysis of the 2010 to 2019 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. 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 heatwave. 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 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 April 19, 2020; the first sortie to be done after COVID-19 restrictions were relaxed and work allowed to resume. We generally try to deploy the mooring in late March in advance of the spring bloom and missed the initiation of the 2020 spring bloom. The profiler did two profiles per day (approximately at the solar minimum and maximum) and there were brief gaps in May and September when the batteries ran out before the weather allowed a service visit (Fig. 3). An unannounced change by the local cellular data provider, in conjunction with an unknown bug in the profiler firmware caused a longer gap in September. The profiler was retrieved October 22, 2020, which is earlier than usual, because we had run out of train wheel anchors and were unable to obtain more in time due to COVID-19 related supply issues, travel restrictions, and a sparse ferry schedule.

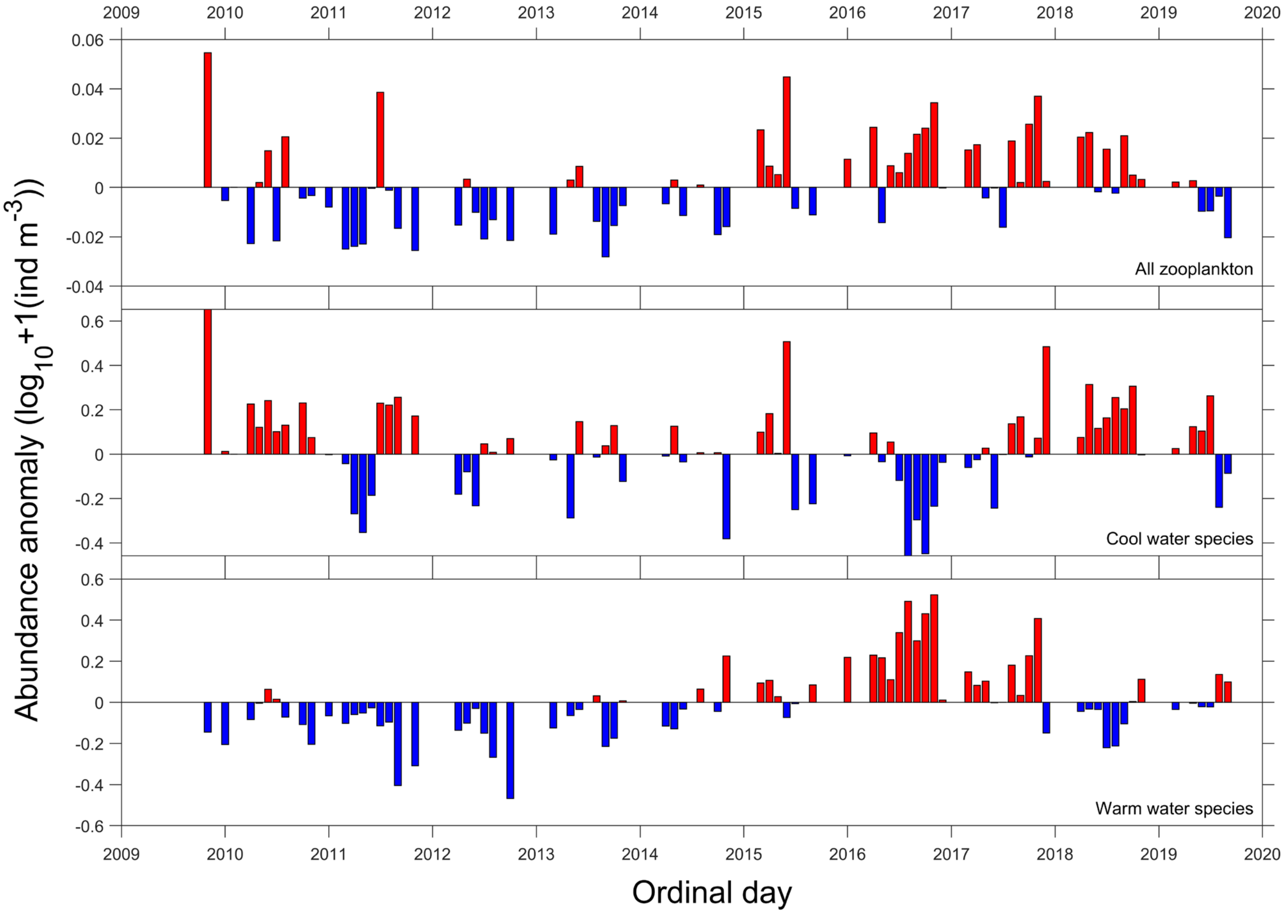

Figure 2. Time series of zooplankton anomalies in PWS, 2010-2018. Zooplankton were divided into "warm" and "cool" water copepod species per Peterson et al. (2017) and average anomalies calculated across groups per Fisher et al. (2015). Warm water species were Calanus pacificus, Clausocalanus sp., Corycaeus 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.

The 2020 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. There was slightly 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 (Fig. 3), 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 that 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).

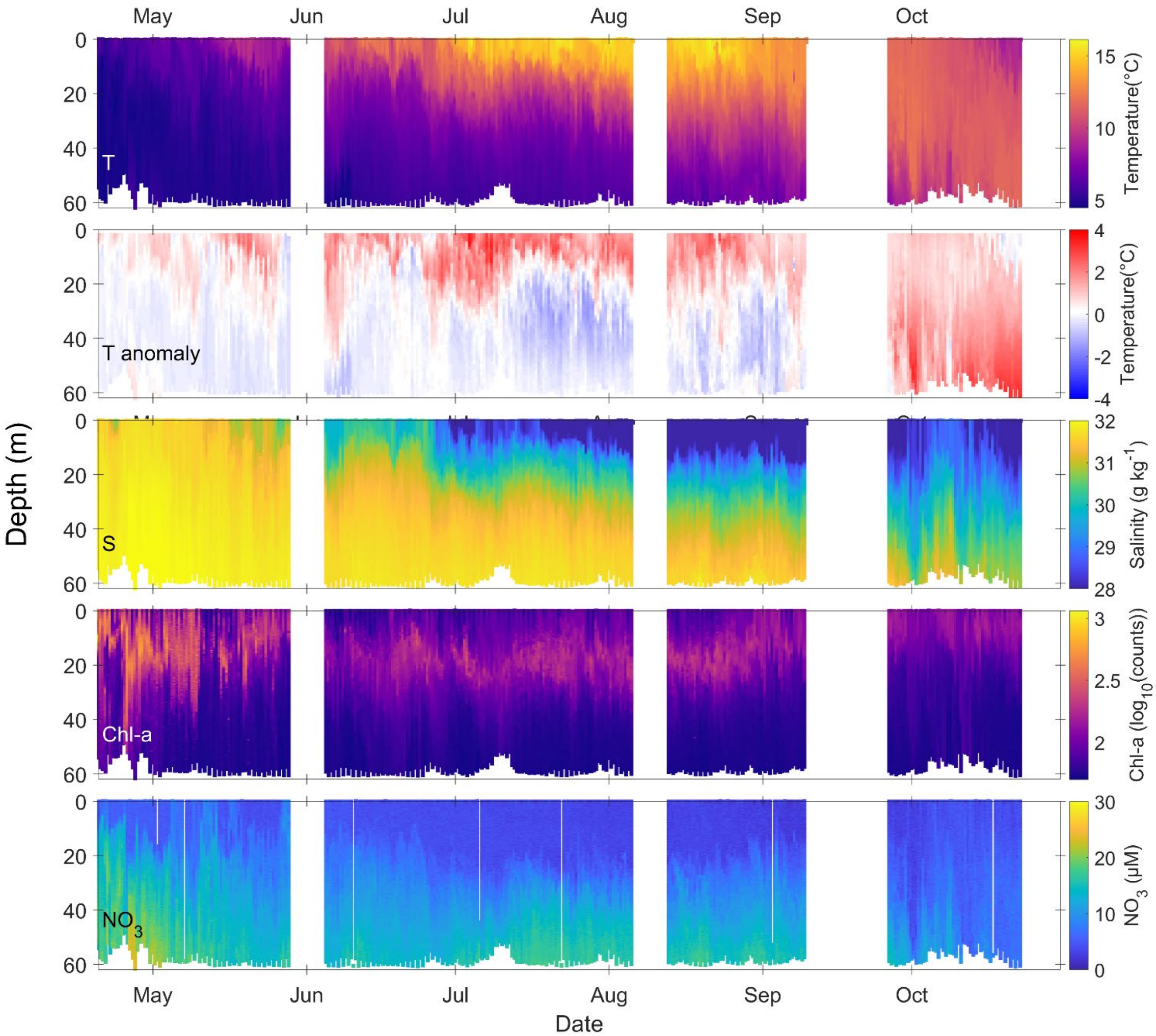

Figure 3. Time series of observations made by the Prince William Sound autonomous profiler in 2019. Top panel: temperature (°C). Second panel: Temperature anomaly (°C). Temperature anomalies were calculated with the method of Campbell (2018) used in Fig. 1. Third panel: Salinity (TEOS-10). Fourth panel: 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 (NPRB). The plankton camera collected 697549 images during the 2020 deployment, occupying just under 19 gigabytes on disk. 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 shown in Fig. 4 for very broad taxonomic categories. In general, there is correspondence between what the net collects and the camera sees in log-log space. 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.

The images collected by the camera allow examining the depth-time relationship of specific taxa groups very fine scales (at least 5 cm in the vertical). For instance, observations of several large taxa show interannual differences, as well as differences among species (Fig. 5). The diel migrant calanoid copepod *Metridia* sp. has what appears to be a consistent change in its depth range each year, that may be in response to changes in the depth range of primary producers (e.g., see the depth of the chlorophyll-a layer in Fig. 3). The pteropod *Limacina helicina* appears to be common in spring through summer and exhibits short blooms of or two weeks in duration. The tunicate *Oikopleura* sp. appears to have been much more variable from year to year, with both short bloom, and multi-week episodes of higher abundance. A manuscript on the use of the classifier to track the annual cycles of specific taxa is in preparation and was the topic of a presentation at the 2020 Ocean Sciences Meeting.

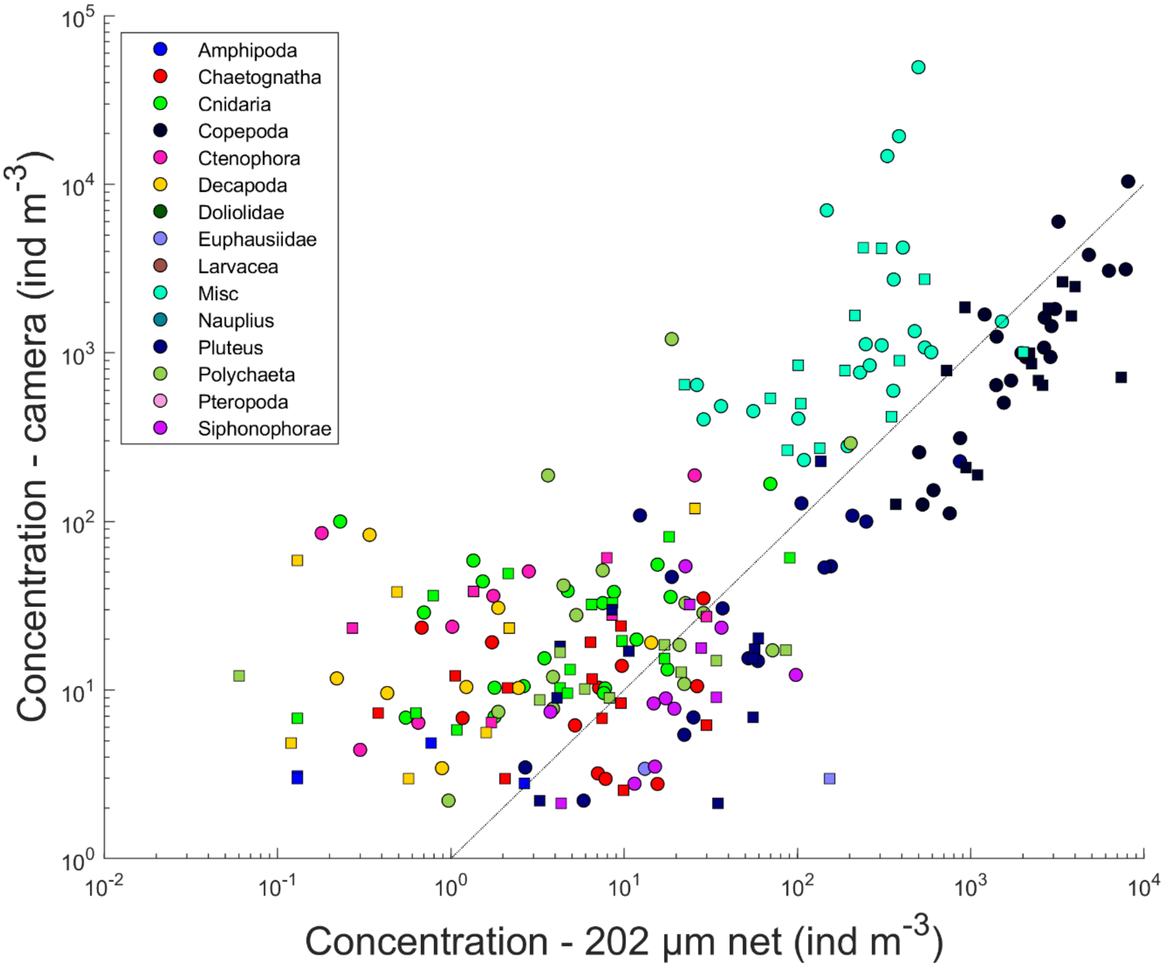

Figure 4. Comparison of abundance estimates derived from the plankton camera aboard the Prince William Sound Profiler (ordinate) and a 202 μm plankton net, by various taxa groups. The dashed line indicates the 1:1 line. Plankton tows were done after profiler service visits, and the tow was done from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

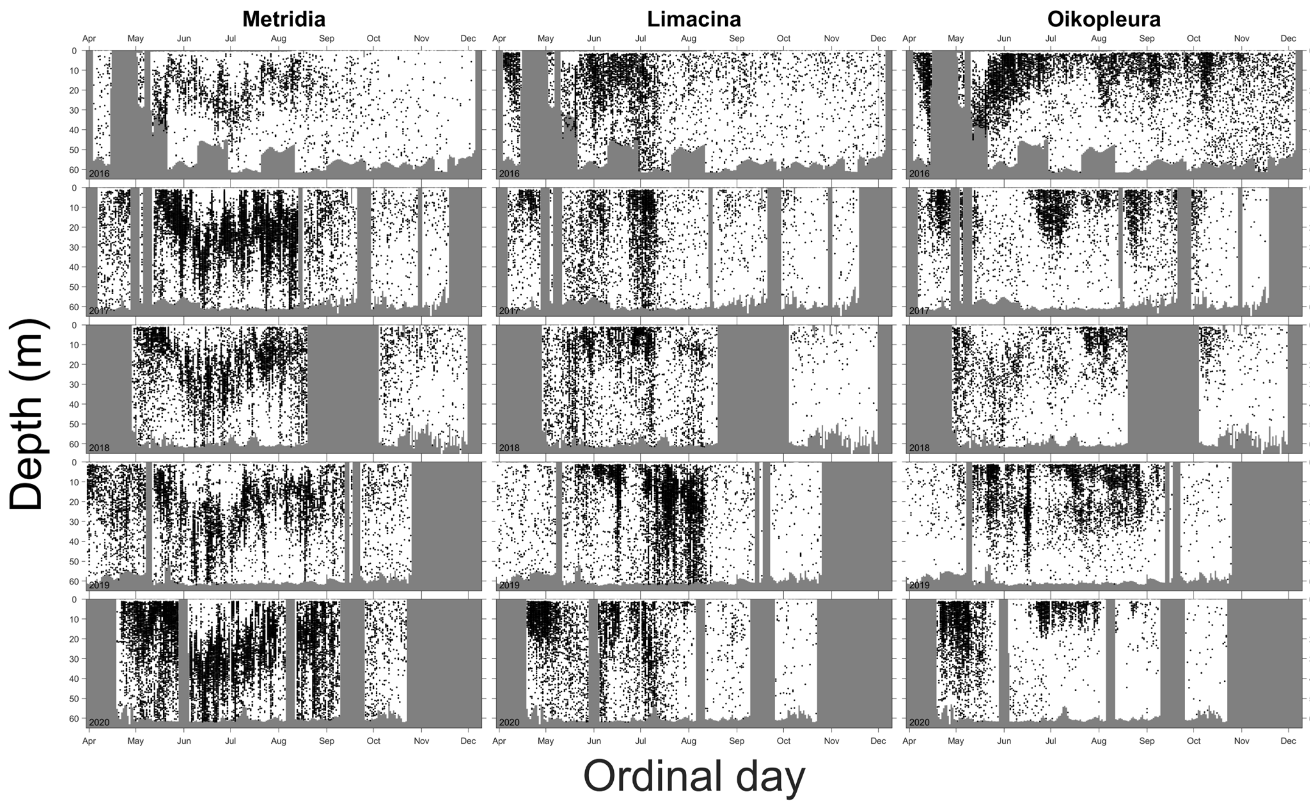

Figure 5. Time-depth distributions of individual plankters of three of the more common large taxa found in the Prince William Sound plankton ecosystem (column-wise: Metridia sp., Limacina helacina, and Oikopleura sp.) in each year of deployments (row-wise with 2016 at the top and 2020 at the bottom). Each point represents an image that was classified as being of an individual plankter of the species. Each image was time-stamped (nearest millisecond) when collected and the depth then determined from the time-pressure record of the CTD on the profiler.

8. Coordination/Collaboration:

A. Long-term Monitoring and Research Program Projects

1. Within the Program

All plankton samples collected as part of project 20120114-J (Long-term monitoring of oceanographic conditions in Cook Inlet/Kachemak Bay) were processed and identified by this project; we are working with PIs Baird and Holderied on a manuscript on the zooplankton of Kachemak Bay and lower Cook Inlet. Because COVID-19 shutdowns of the federal labs led to the cancellation of forage fish collection activities and aerial survey validations by Arimitsu (project 20120114-C), we conducted some validations for her project during our regular cruises, and did some extra sorties to collect forage fish samples. Following advice from the Science Panel in 2018, modifications were made to the PWS Science Center vessel to accommodate a bird observer from project 20120114-E (Fall and Winter seabird abundance). Joint cruises were completed in February-March and November 2020 and are planned to continue going forward. We contributed temperature and zooplankton data and participated in the drafting of three GWA science synthesis manuscripts, led by Suryan (project 20120114-A), Arimitsu (project 20120114-C), and Danielsen (project 20120114-I).

2. **Across Programs**

   a. **Herring Research and Monitoring**

   Technicians from project 20160111-B (Annual Herring Migration Cycle) have participated in surveys done by this project to upload data from the tracking arrays in Hinchinbrook Entrance and Montague Strait and to recover/deploy receivers in other locations in PWS. A receiver was also installed on the profiling mooring in 2019 and 2020 to further extend the reach of the array. Campbell has been collaborating with Bishop and PI Danielson (GWA project 20120114-I) to deploy an oceanographic glider with and onboard receiver in PWS, the glider was deployed in late January. Campbell is also collaborating with postdoctoral researcher Bia Diaz on her work examining variations in herring spawn timing in PWS (project 20120111-C).

   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

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).

C. With 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 (ADF&G) is doing their surveys (contact: Stormy Haught, Alaska Department of Fish and Game, Cordova). The April cruise was delayed, but we did attempt (unsuccessfully) to collect fish from some small spawning aggregations we observed.

A NPRB 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) is the lead PI and Campbell is 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 (Ferriss and Zador 2020) on: zooplankton and 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.

The cameras will be developed for Eshamy Creek, a small sockeye, pink, and coho salmon stream in PWS that has historically been managed in part with a small weir where fish passage was directly counted, but which was cancelled due to budget cuts in 2011. The project will fund ADF&G (lead: Jeremy Botz, Area Management Biologist, Cordova) to redeploy the Eshamy Creek weir to provide training images and ground-truth data for the camera systems, and to provide direct passage counts for use in in-season management of salmon fisheries in western PWS for 2021 and 2022. If successful, the cameras are expected to be an economical method for estimating fish passage that will complement or potentially replace other existing methods.

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. In preliminary tests with scale images of Copper River sockeye furnished by Rachel Ertz and Stormy Haught at ADF&G in Cordova, the plankton optimized classifier identified year 1-2 freshwater-ocean fish with 100% accuracy and year 1-3 fish with 91% accuracy "out of the box" with no modifications. We are currently adding to the scale images set and refining the algorithms and have begun work on a proposal to be submitted to NPRB to develop the method further.

9. Information and Data Transfer:

A. Publications Produced During the Reporting Period

1. Peer-reviewed Publications

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.

Connors, B., M.J. Malick, G.T. Ruggerone, P. Rand, M. Adkison, J. Irvine, **R. Campbell**, and K. Gorman. 2020. Climate and competition influence sockeye salmon population dynamics across the Northeast Pacific Ocean. Canadian Journal of Fisheries and Aquatic Sciences. doi:10.1139/cjfas-2019-0422.

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.M. Suryan, S. Batten, M.A. Bishop, R.W. Campbell, H. Coletti, D. Cushing, K. Gorman, S. Hatch, S. Haught, R.R. Hopcroft, K.J. Kuletz, C. Marsteller, C. McKinstry, D. McGowan, J. Moran, R.S. Pegau, A. Schaefer, S. Schoen, J. Straley, and V.R. von Biela. 2019. Chapter 3 Synchronous collapse of forage species disrupts trophic transfer during a prolonged marine heatwave. In R.M. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Final Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Campbell, R.W. 2020. Monitoring the Oceanographic Conditions of Prince William Sound. FY19 annual report to the *Exxon Valdez* Oil Spill Trustee Council, project 19120114-G.

Danielson, S.L., T.D. Hennon, D.H. Monson, R.M. Suryan, R.W. Campbell, S.J. Baird, K. Holderied, and T.J. Weingartner. 2020. Chapter 1 A study of marine temperature variations in the northern Gulf of Alaska across years of marine heatwaves and cold spells. In R.M. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Final Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Suryan, R.M., M. Arimitsu, H. Coletti, R.R. Hopcroft, M.R. 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, K. Kuletz, B. Laurel, J.M. Maniscalco, C. Matkin, C. McKinstry, D. Monson, J. Moran, D. Olsen, S. Pegau, J. Piatt, L. Rogers, A. Schaefer, J. Straley, K. Seeeney, M. Szymkowiak, B. Weitzman, J. Bodkin, and S. Zador. 2020. Chapter 4 Ecosystem response to a prolonged marine heatwave in the Gulf of Alaska. In R.M. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Draft Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

3. Popular articles

Campbell, R.W., J. Jaffe, and P. Roberts. 2020. Computers identify plankton images from Prince William Sound. PWSSC Delta Sound Connections (https://pwssc.org/wp-content/uploads/2020/07/DSC-2020-web.pdf).

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.A. Bishop, R.W. Campbell, H. Coletti, D. Cushing, K. Gorman, R. Hopcroft, K. Kuletz, C. Marsteller, C. McKinstry, D.

McGowan, J. Moran, S. Pegau, A. Schaefer, S. Schoen, J. Straley, and V. von Biela. 2021. Heatwave-induced synchrony within forage fish portfolio disrupts energy flow to top pelagic predators. Alaska Marine Science Symposium, online, Jan 26-28.

Campbell, R.W., P.L. Roberts, and J. Jaffe. 2020. The Annual Secondary Productivity Cycle in Prince William Sound Measured with the Prince William Sound Plankton Camera. ASLO Ocean Sciences Meeting, San Diego 16-21 February.

Campbell, R.W. 2021. Impacts of the recent marine heat waves on the oceanography and plankton ecosystem of Prince William Sound. Alaska Marine Science Symposium, online, Jan 26-28.

Dias, B.S., D.W. McGowan, R.W. Campbell, and T.A. Branch. 2021. What affects spawning phenology of herring (*Clupea pallasii*) in Prince William Sound? Alaska Marine Science Symposium, online, Jan 26-28.

Du., X., R.W. Campbell, S. Kibler, and B. Wright. 2021. Seasonal dynamics of the harmful dinoflagellate *Alexandrium* and associated paralytic shellfish toxin contamination in shellfish: NPRB 1801 project updates for Prince William Sound. Alaska Marine Science Symposium, online, Jan 26-28.

Renner, M., K. Holderied, C. McKinstry, D. Hondolero, and R.W. Campbell. 2021. Is it spring yet? Seasonal clusters of phyto- and zooplankton communities in Kachemak Bay and Lower Cook Inlet. Alaska Marine Science Symposium, online, Jan 26-28.

2. Public presentations

Campbell., R.W. 2020, Effects of the recent marine heat waves on the waters of Prince William Sound. Prince William Sound Natural History Symposium, online, May 18.

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

No new contributions for this reporting period. We continue to update annual ecosystem indicators for the NOAA Ecosystem Status Report as stated in section 8.C.

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

2020 CTD data and 2019 zooplankton data have been uploaded to the workspace (https://workspace.aoos.org/project/23640/folder/2638352/pws-oceanography-data,-2017-2021). 2020 Chlorophyll-a data will be uploaded when analysis has been completed.

10. Response to EVOSTC Review, Recommendations and Comments:

Science Panel Comment (FY21): The proposal makes a general statement about some unspent funds that the PIs will work to draw down as they catch up on our work. Please provide an update on the sample analysis and a more concrete plan (or options) for expenditure of unused funds.

GWA PI Response (FY21 Work Plan): Analysis of zooplankton samples is continuing the 2019 samples, there are still two Prince William Sound cruises to process and most of the 2019 Kachemak Bay samples to do. Staff quarantine and the pandemic shutdown stopped work entirely for almost two months, and the need to minimize overlaps by staff in the lab resulted in reductions in throughput for several weeks. Part of the time away from the lab was used to focus on a manuscript on the Kachemak Bay plankton time series which is nearly ready to submit.

Analysis of zooplankton samples has now been ramped up under phase 3/4 of the Reopen Alaska Responsibly plan. At current rates we estimate that if things go extremely well, we may be able to have the samples counted by the usual January deadline; at worst we should be a month or two late.

We will be hiring a second technician to help with the analysis of phytoplankton and nutrient samples. At projected maximum burn rates we think we may be able to catch up on unspent funds by January, but expect to roll over a small amount (likely < $25K) because we anticipate that the second technician will still be working on samples into the next fiscal year of the project and that expense is unbudgeted in year 5. We do not currently expect that we will need to roll over funds beyond FY21.

Going forward, we anticipate no issues in conducting the work planned for this project, assuming the number of COVID-19 cases in Cordova remains low.

Additional GWA PI Response (FY20 Annual Report): We have been continuing to catch up on sample processing. PWS Zooplankton samples from 2019 were completed in January and have been uploaded to the workspace, as has the 2020 CTD data. One technician is now working on the Kachemak Bay zooplankton samples from 2019, and a second is working through the chlorophyll-a samples. The rollover of funds into FY21 was larger than expected, but we will continue to spend it down as we catch up on samples and ramp up for the FY21 field year.

Science Panel Comment (FY20): The Science Panel is pleased that the plankton camera is running again on the autonomous profilers. We note this project continues to be productive. Data show the magnitude of bloom has changed but the timing has not. Do you have indications about the reasons for these findings? Might it have something to do with increased water column stability and reduced nutrient flux (freshwater input and/or upwelling)? Is there some indication about the potential influences of increased temperature, freshwater input (e.g., increased glacial melt), or photoperiod? This project, and two others, noted the switch among warm- and cold-water zooplankton. Is there evidence to indicate the mechanism to be differential local production or advection of these species from other areas? The Panel appreciates the amount and quality of the data and would like to see if data analyses can address the questions above.

GWA PI Response (FY20): I thank the science panel for their comments. The mechanisms forcing the spring bloom in Prince William Sound (PWS) are as complicated as one might expect, and the first approximation appears to be an interaction between light, stability (primarily thermal but also salinity), and wind mixing (Eslinger et al. 2001: doi 10.1046/j.1054-6006.2001.00036.x; Henson, 2007: doi 10.1357/002224007784219002). Stability is set up in ~April/May and the bloom initiates if it is not disrupted by wind mixing. The timing of the bloom will therefore depend on the timing of stability onset and wind events, while the magnitude will depend on the amount of nitrate available at the surface -- the bloom terminates after nitrate is depleted in surface waters.

We do not have a tremendously long time series of the nutrient biochemistry in PWS, but the system is largely advective, and much of the nitrate input is likely from deepwater renewal events that bring in off-shelf waters (high salinity, low oxygen and high nitrate) to the basins of PWS in summer when downwelling relaxes. That deep water is mixed up into the surface waters over the winter and is what drives the spring bloom. At depth in PWS there is a modest trend towards increased salinity over the last few decades (Campbell, 2018: doi 10.1016/j.dsr2.2017.08.014), which is presumably driven by decreased downwelling and enhanced deepwater transport. That would imply that nitrate flux might actually be increasing somewhat in the deep waters of PWS.

The Campbell (2018) study also found a shoaling of mixed layer depths in the last 40 years, which seems a likely explanation for the reduction in overall productivity, as the science panel suggests. An interesting pattern that we have observed at the profiler site since the onset of the 2013-2014 marine heat wave (MHW) is a fairly consistent negative temperature anomaly in waters immediately underlying the mixed layer. This can be seen in 2018 in the profiler temperature anomaly panel (2nd from top) of Fig. 7 of the project 20120114-G FY20 work plan. Given that deep waters of PWS are exhibiting a warming trend, the presence of a cold anomaly suggests to me that the surface mixed layer is much thinner presently than in the climatology, which manifests as cooler anomalies at depth. In other words, the shoaling and strengthening of the mixed layer means that "deep water" (which is cooler) is found closer to the surface than previously. It follows that the total amount of near-surface nitrate available to the phytoplankton in the seasonal mixed layer will be reduced which will ultimately result in a smaller bloom.

With regard to zooplankton species compositions, even prior to the MHW, Russ Hopcroft (Seward Line PI) and I noticed that the species we designate now as "warm species" were often present in PWS in low abundance, but comparatively rare on the shelf along his GAK line. We hypothesized that PWS may be a refugium of sorts for those species. Smaller embayments around the periphery of PWS (particularly the non-glaciated ones) can become considerably warmer in summer than central PWS or on the shelf. So, the MHW may have made the environment in PWS a more amenable habitat to those species, and conversely less amenable to the canonical subarctic taxa we designate as "cool water" ones. The two year lag between the onset of the MHW and the largest anomalies is interesting, but could be due to enhanced local production or advection -- they are not mutually exclusive. It seems likely that the reality was a mix of the two - some species have always been present and did better doing the MHW years (a closer look at stage compositions may be informative), while others were advected northward by the prevailing currents. At least one species, *Corycaeus anglicus*, was extremely rare prior to the MHW (not seen some years, 1-2 observations in others) but is now prevalent throughout PWS.

The questions highlighted by the science panel are of considerable interest and are the focus of ongoing analyses that the science panel can expect to see in future reports. Our focus in the last years was fairly broad descriptive manuscripts on the hydrography and the plankton ecosystem in PWS (published in the Gulf Watch Alaska/Herring Research and Monitoring Deep-Sea Research II volume). In FY19 we have been focused on synthesis activities, a manuscript on the profiler and plankton camera (reviews received September 23, 2019 and will be accepted pending revisions), and a manuscript in preparation on the Kachemak Bay plankton ecosystem. We are looking forward to diving into more of the details in future work.

11. Budget:

Please see provided program workbook. Spending on this project was slightly delayed in FY20, because other projects that were concluding needed to be spent down, and because of some modest delays due to the COVID-19 shutdowns in March-April.

***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	$145.0	$149.3	$153.8	$158.4	$163.2	$769.7	$516.5
Travel	$1.0	$1.0	$1.0	$1.0	$1.0	$5.0	$11.2
Contractual	$43.7	$43.7	$43.7	$43.7	$43.7	$218.3	$206.3
Commodities	$11.0	$11.0	$11.0	$11.0	$11.0	$55.0	$28.7
Equipment	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Indirect Costs (*waived*)							
SUBTOTAL	$200.6	$205.0	$209.5	$214.1	$218.8	$1,048.0	$762.7
General Administration (9% of subtotal)	$18.1	$18.4	$18.9	$19.3	$19.7	$94.3	N/A
PROJECT TOTAL	$218.7	$223.4	$228.3	$233.3	$238.5	$1,142.3	
Other Resources (Cost Share Funds)	$300.0	$300.0	$275.0	$275.0	$275.0	$1,425.0	

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