EVOSTC FY17-FY21 INVITATION FOR PROPOSALS
FY21 (YEAR 10) CONTINUING PROJECT PROPOSAL SUMMARY PAGE

Project Number and Title

Gulf Watch Alaska: Environmental Drivers Component Project

21120114-G—Long-term monitoring of oceanographic conditions in Prince William Sound

Primary Investigator(s) and Affiliation(s)

Robert W. Campbell, Prince William Sound Science Center

Date Proposal Submitted

August 14, 2020

Project Abstract

This project will continue physical and biological measurements to assess trends in the marine environment and bottom-up impacts on the marine ecosystem of Prince William Sound (PWS). Regular (~6 per year) vessel-based surveys of PWS will be conducted to maintain ongoing time series observations of physical (temperature, salinity, turbidity), biogeochemical (nitrate, phosphate, silicate, dissolved oxygen), and biological (chlorophyll-a concentration, zooplankton abundance and composition) parameters in several parts of PWS. Sampling sites include central PWS, the entrances (Hinchinbrook Entrance and Montague Strait), and four priority bays that were part of the *Exxon Valdez* Oil Spill Trustee Council-funded Sound Ecosystem Assessment project in the 1990s and the ongoing Herring Research and Monitoring project.

Additionally, an autonomous profiling mooring will be deployed in central PWS to provide high frequency (twice daily) depth-specific measurements of the surface layer that will be telemetered out in near real-time. The profiler will include measurements that complement the survey activities (temperature, salinity, oxygen, nitrate, chlorophyll-a, turbidity). An *in situ* plankton camera was recently developed for the profiler and is used to enumerate zooplankton, large phytoplankton and other particles, with some taxonomic discrimination.

Spring and early summer observations in PWS indicate the timing of the spring bloom was near the climatological average and is continuing a trend towards lower productivity over time – satellite chlorophyll observations in spring 2020 have been the lowest in the 23-year record. Following a winter of temperatures near the climatological average, the surface layer in central PWS returned to above average temperatures in 2020, to approximately the same levels as during the marine heatwave of 2013-2016. COVID-19 impacts to this project were delays to one survey (spring bloom cruise) and sample analyses in the laboratory. The remaining cruises in 2020 should proceed as planned. We are not proposing any major changes to this project for FY21.

EVOSTC Funding Requested* ***(must include 9% GA)***

FY17	FY18	FY19	FY20	FY21	TOTAL
$218,700	$223,400	$228,300	$233,300	$238,500	$1,142,300

Non-EVOSTC Funds to be used, please include source and amount per source: (see Section 6C for details)

FY17	FY18	FY19	FY20	FY21	TOTAL
$300,000	$300,000	$275,000	$275,000	$275,000	$1,425,000

1. PROJECT EXECUTIVE SUMMARY

The Environmental Drivers component of the Gulf Watch Alaska (GWA) program provides the spatial and temporal context for understanding change in the physical and chemical environment. Abiotic environmental changes will mediate lower trophic level (phytoplankton and zooplankton) productivity changes and subsequently propagate to mid and upper trophic level consumers. As in the first 5 years of GWA, this observation network consists of five interconnected projects distributed across the spill-impacted Gulf of Alaska (GOA). The focus of this project is oceanographic surveys of Prince William Sound (PWS) bays and entrances that builds upon over 4 decades of prior work.

Within PWS, variations in annual productivity have been posited to vary with changes in upwelling/downwelling and the track of the Alaska Coastal Current (ACC; the River-Lake hypothesis of Cooney 2001a). Some support was found for the hypothesis for some years (1981-1991), but not in others (Eslinger et al. 2001). The hypothesis has not been revisited since 2001. In the greater GOA, it has been suggested that salmon returns are mechanistically linked to zooplankton and phytoplankton productivity via large scale atmospheric and oceanographic processes (the Optimal Stability Window hypothesis of Gargett 1997). It has been suggested that retrospective data are lacking to test the hypothesis, but that long time series of hydrographic profiles and biological observations are one way to move forward (Gargett et al. 1998). Additional hypotheses include assessing the role of turbidity. The southern coast of Alaska is currently losing ice mass at some of the highest rates on earth (Jacob et al. 2012), which may be accompanied by increases in surface layer turbidity, which could then decrease phytoplankton growth rates. Similarly, increases in freshwater inputs can be expected to have an impact on the timing of springtime stability, and the depth of the annual mixed layer where productivity occurs.

The goal of this project is to continue the time series of oceanographic observations in PWS that began in 2009 under the GWA program and to continue to put the new data into context with a 45-year conductivity-temperature-depth (CTD) database that was assembled during the first five years of GWA (Campbell 2018; Fig. 1). These data will be used to observe and describe how the region is changing in response to the 2013-2016 and 2019 marine heatwaves, and to begin to address the many hypotheses for the mechanisms that are driving productivity in the region. In addition to more traditional vessel-based surveys to assess spatial variability of environmental drivers, a state-of-the-art autonomous profiling mooring will be used to observe the annual cycle of physical, biogeochemical, and biological metrics in central PWS at very high frequency.

During the first 5 years of this project (16120114-E), we conducted an exhaustive effort to compile all historical CTD casts in the region (Campbell 2018). That database has been continually combined with the data collected by the GWA program and contains 23,981 unique profiles dating back to 1974. Temperature anomalies show a warming trend over the last 45 years at most depths (Fig. 2). The temperature trend at the surface is has the weakest trend, presumably due to enhanced inputs of cold meltwater at the surface along the margin of the GOA (Campbell 2018).

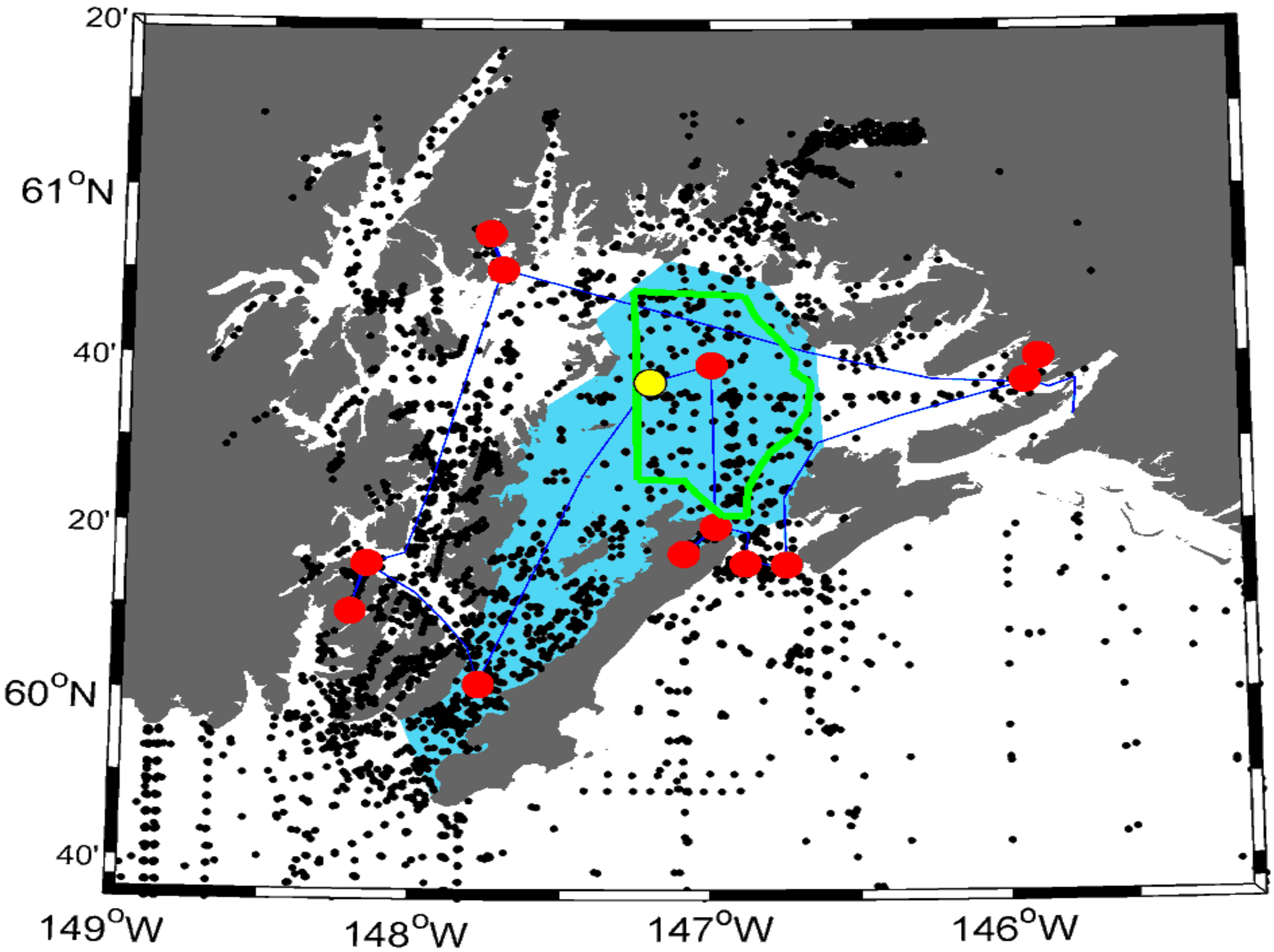

Figure 1. Prince William Sound (PWS). Black dots indicate the position of CTD casts done from 1974-2019. Red dots indicate the stations visited during vessel surveys (this study), and the blue line indicates the standard vessel track. The yellow dot indicates the position of the autonomous profiling mooring. The blue area is the "central PWS" region and was the area used to determine anomalies (see Fig. 2). The green polygon is the area within which MODIS/seaWIFS chlorophyll data were averaged.

In late 2013, temperature anomalies shifted to primarily positive (Fig. 2), like those observed throughout the GOA (Bond et al. 2015). Anomalies within PWS in 2015 were as much as 2°C above average (4°C above average at the profiler site), which appears to have caused numerous changes in the marine ecosystem including observations of rare southern species; mortality events in birds, mammals and starfish; and larger than average blooms of toxin producing phytoplankton (e.g., Zador et al. 2019). Temperature trends in 2017 suggested a return to temperatures near the long-term average, but anomalies in 2018 and 2019 were again primarily positive (Fig. 2). Temperature anomalies in 2019 were the highest observed over the 46-year CTD time series and 2019 has been designated as a second marine heatwave distinct from 2013-2016 heat wave (aka "The Blob"; Amaya et al. 2020). Amaya et al. (2020) suggests that the genesis of the 2019 heatwave was a summertime weakening of the North Pacific high pressure system, while the 2013-2016 heat wave was due to a weakening of the Aleutian Low in winter (Bond et al. 2015).

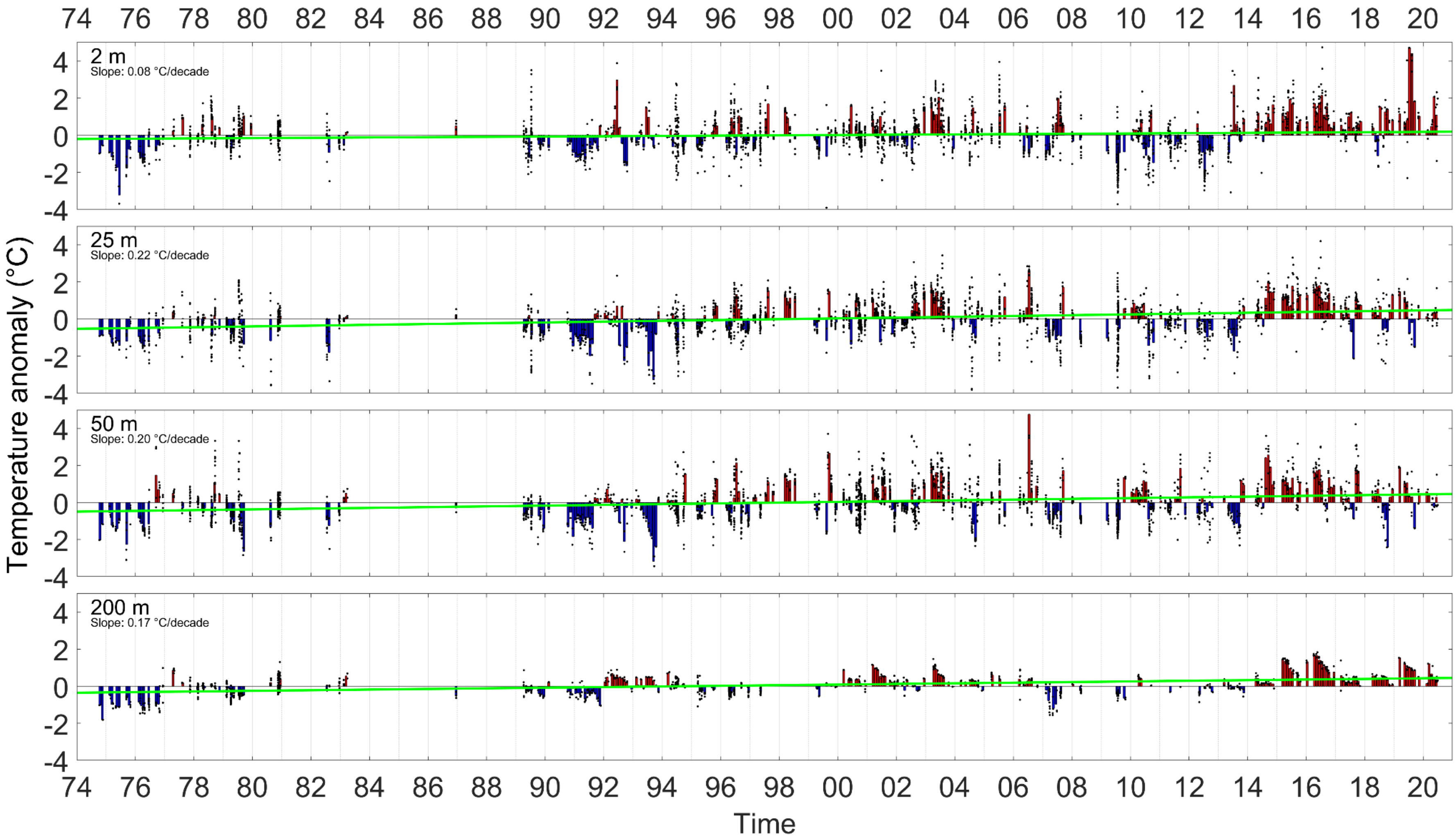

Figure 2. Temperature anomalies at four selected depths in central PWS (the blue-shaded area in Fig. 1). Anomalies were calculated as the residual to a second order cosine curve fit to all years data (to remove seasonality: Campbell 2018). Black points are observations, bars are monthly averages, and the green line indicates the linear trend. All slopes were significantly different from zero ($p<0.05$).

A time series of surface chlorophyll concentrations in central PWS (see Fig. 1) was assembled from sea-viewing wide field-of-view sensor (seaWIFS) and moderate resolution imaging spectroradiometer (MODIS) satellite chlorophyll products (downloaded from the National Oceanic and Atmospheric Administration (NOAA) CoastWatch Program and the National Aeronautics and Space Administration's (NASA's) Goddard Space Flight Center OceanColor Web). Examination of the satellite chlorophyll records from central PWS (Figs. 3, 4) shows that the timing of the spring phytoplankton bloom in 2020 was at approximately the climatological average but was rather brief. In general, the magnitude of the spring bloom has been declining over the last two decades, and 2020 has had the lowest integrated chlorophyll values observed in the 23 year satellite record; there is not any indication that the timing of the bloom has changed (Fig. 4).

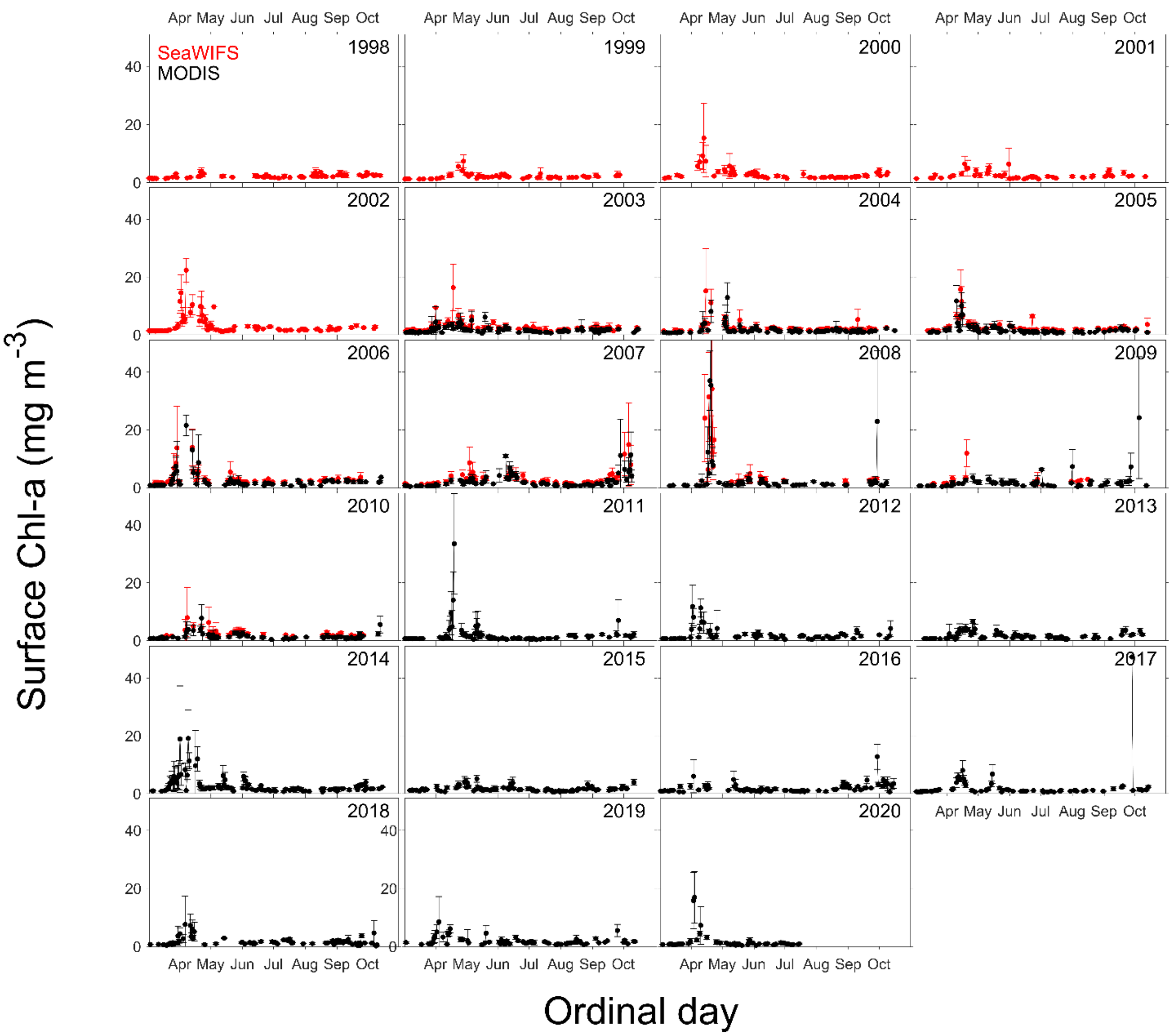

Figure 3. Surface chlorophyll-a time series in central Prince William Sound (PWS). Daily mean and standard deviations within non-cloud-masked pixels in central PWS (inside the green polygon in Fig. 1) are shown. The seaWIFS and MODIS data were examined for an offset between the two during years when the two time series overlapped (2003-2010). SeaWIFS chlorophyll estimates tended to be slightly lower than MODIS estimates (slope = 0.88, intercept =0.7749) and were adjusted to make the estimates comparable. Data were downloaded from the National Oceanic and Atmospheric Administration's CoastWatch Program and National Aeronautic and Space Administration's Goddard Space Flight Center OceanColor Web (https://coastwatch.pfeg.noaa.gov/erddap/griddap/index.html; data products erdMBchla1day and erdSW2018chla1day).

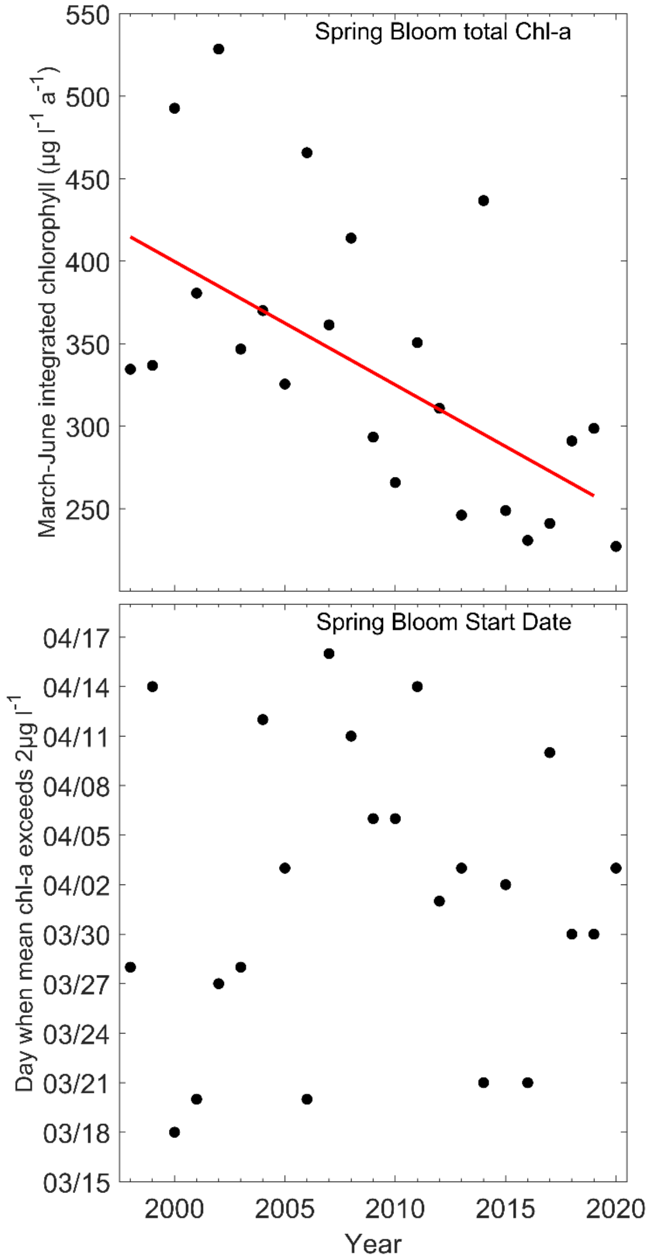

Figure 4. Estimates of the magnitude (top panel) and onset (bottom panel) of the spring bloom in central Prince William Sound (same data as Fig. 3). The magnitude of the bloom was estimated by numerically integrating chlorophyll concentration from March 1 to June 31 in each year using the trapezoid rule. The onset of the bloom was estimated as the day of the year when surface chlorophyll concentrations first exceeded 2 μg l^{-1}. On dates when there was an estimate from both the seaWIFS (adjusted for offsets) and the MODIS time series available, the midpoint was used.

The PWS Profiling mooring is an early variant of the WETLabs Thetis profiler (https://www.seabird.com/asset-get.download.jsa?code=251257) that was purchased in 2013. It consists of a large frame, onboard electronics and winch. Syntactic foam buoyancy is attached to the top of the frame, and it is ballasted to have approximately 20 lbs of positive buoyancy. The profile spends most of its time at a specified park depth (60 m), and at specified intervals (usually twice per day at the solar minima/maxima) the profiler comes out of a low power sleep state, powers up the instruments, and begins paying out line to allow the frame to ascend to the surface. After piercing the surface, data and instructions are telemetered through a cellular data connection, after which the profiler returns to the park depth and re-enters low power mode (Fig. 5). The instrument suite on the profiler includes a CTD recorder, chlorophyll-a fluorometer, turbidometer, oxygen sensor, and nitrate sensor. Power is provided by a 1.5kW lithium-ion battery, which carries enough charge for ~90 60m to surface profiles. Profiles are done twice daily, at the solar maximum and minimum.

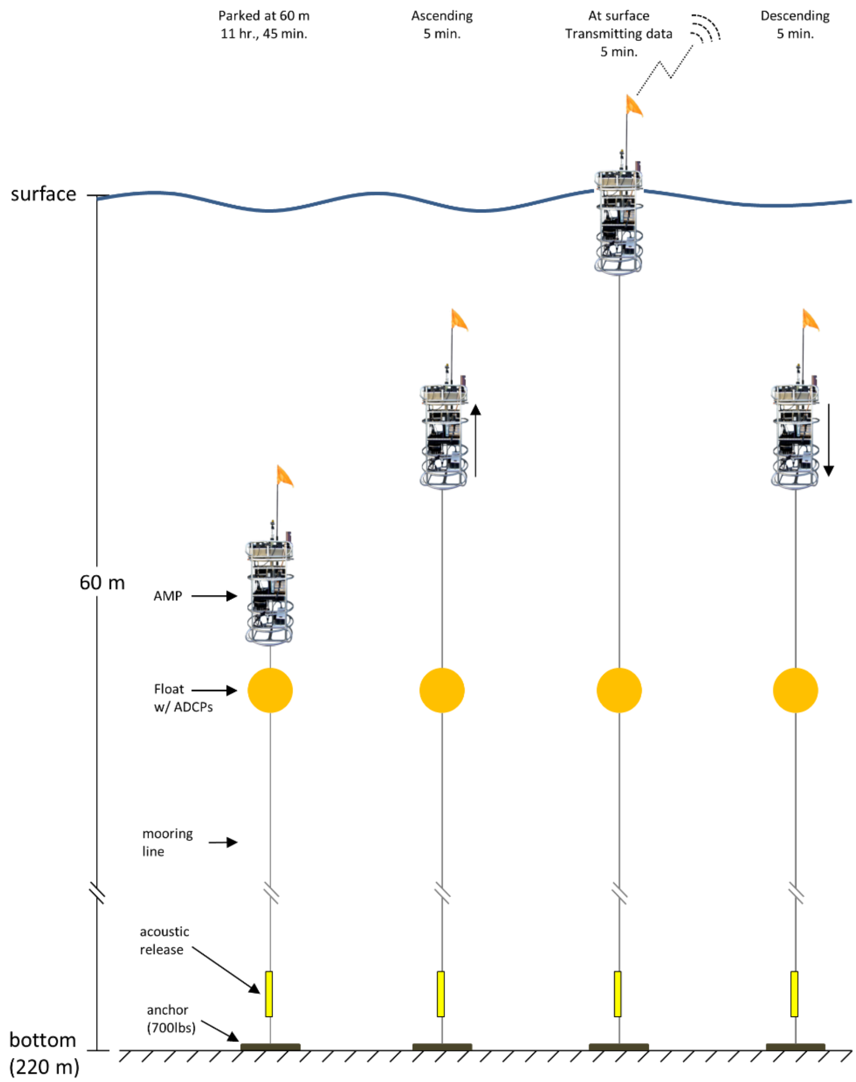

Figure 5. Schematic of the profiling mooring during a profiling cycle.

The PWS profiler obtains a very high resolution picture of the evolution of the surface oceanography in the Sound, which is shown for the 2019 deployment in Fig. 6. The onset of thermal stratification may be seen in early May and the accumulation of heat throughout the summer months is evident (Fig. 6, 1st [top] panel). Similarly, the reduction in salinity over the summer months (driven by relaxed wind mixing, precipitation, and ice and snowmelt) is captured (Fig. 6, 2nd panel). The surface and subsurface spring bloom may be seen in late April/early May in the chlorophyll-a data (Fig. 6, 3rd panel) and the concomitant depletion of surface nitrate (Fig. 6, 4th panel). Following the depletion of surface nitrate, a subsurface chlorophyll maximum establishes at the nitricline, which is disrupted in the autumn months as thermal and salinity stratification breaks down.

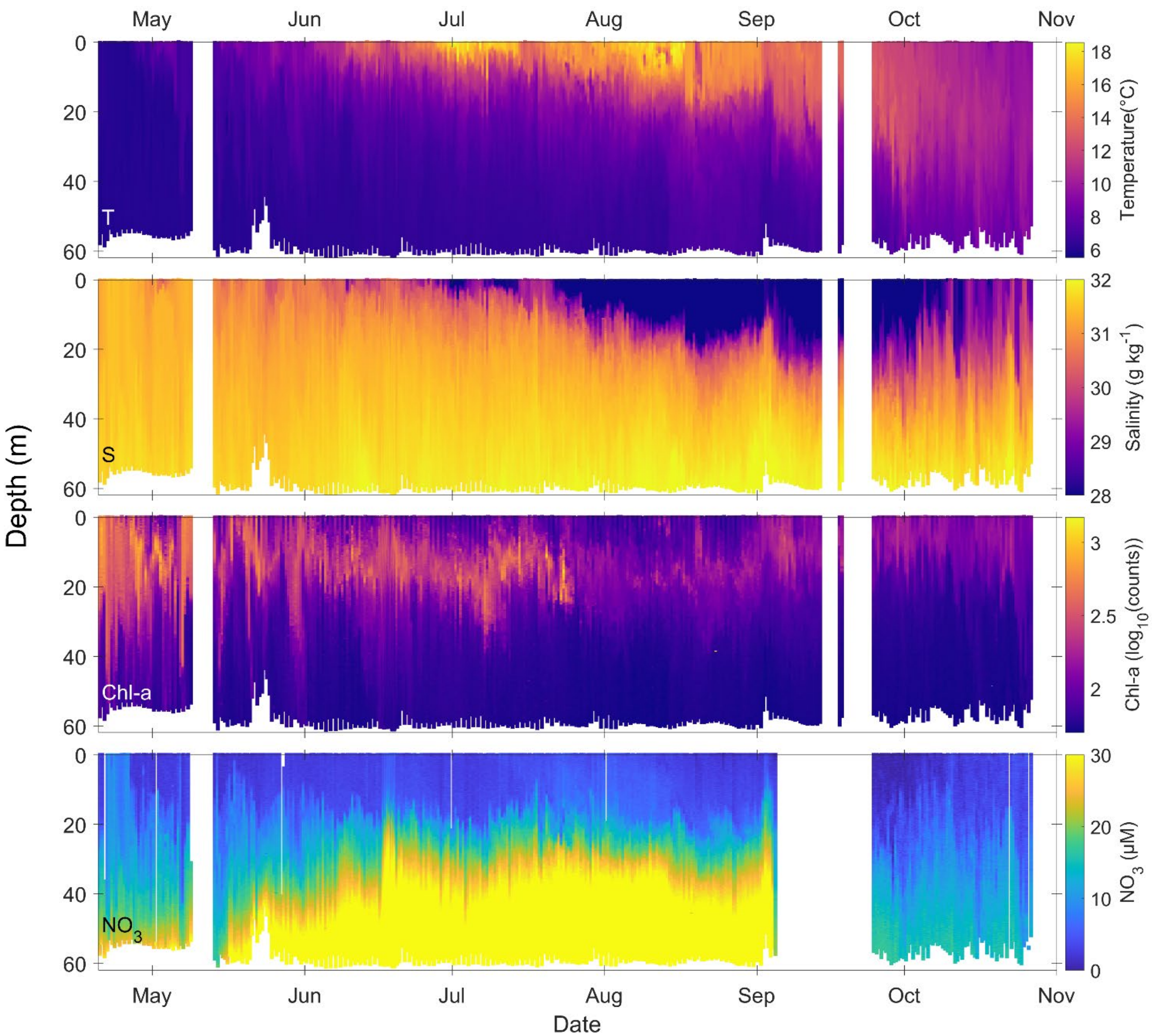

Figure 6. Time series of observations made by the Prince William Sound autonomous profiler in 2019. Top panel: temperature. Second panel: salinity. Third panel: chlorophyll-a, presented as log10 transformed digital counts (counts are linearly proportional to chlorophyll-a concentration). Bottom panel: Nitrate concentration. White spaces are data gaps; the May gap was caused by weather delaying a service visit to replace the batteries. The September gap was caused by an issue with the nitrate sensor and a failure in the winch electronics.

Deployments of the profiler began in 2014, which is when the northern GOA began experiencing its current warm stanza. Although there are not profiler data from before the heatwaves, the Campbell (2018) CTD database (which is continually updated as part of this project) may be used to convert the profiler temperature time series to an anomaly time series to examine how the near surface temperature climate in PWS has changed in recent years (Fig. 7). A number of interesting patterns are evident when examining the temperature anomalies, including the following:

- The onset of warming in early 2014 was captured and persistent surface warm anomalies were present in 2015 through 2017. An analysis of heat flux from the mid-PWS NOAA weather buoy (Campbell, unpublished) found that outward heat fluxes in PWS were low in 2014, which suggests that the genesis of the warm anomalies in PWS was the same as the rest of the GOA (a reduction in winter mixing and retention of heat: Bond et al. 2015). Warm anomalies persisted in PWS into 2017, which may have been caused by transport from the adjacent GOA (temperatures in PWS tend to lag the GOA by about a year: Campbell 2018). Near surface temperature anomalies were near climatology in 2018 and were very warm in 2019 (5°C above the long-term average). Near surface temperature anomalies in 2020 continue to trend warm as of late July.
- Cool anomalies at depth immediately below the surface layer persist during the summer months in most years. Absent a plausible mechanism for the subsurface injection of cooler waters, the cool anomalies seem likely to be a manifestation of a reduction in the depth of the surface mixed layer caused by the increased heat retained in the surface layer and increased stability, plus the reduction in wind mixing caused by the changes in atmospheric circulation that are hypothesized to have caused both heatwaves (Bond et al. 2015, Amaya et al*.* 2020). In other words, a stronger, warmer, thinner mixed layer will inhibit the mixing of heat downward in the water column and thus present as a negative anomaly immediately below the mixed layer, because deep waters tend to be cooler. Musgrave et al*.* (2013) calculated spring/summer mixed layer depths in central PWS to be in the range of 10 to 40 m, which would support this suggestion of a deeper average mean mixed layer depth than is occurring in recent years (the anomaly plot suggests mixed layer depths on the 5-25 m range). The Musgrave et al*.* (2013) data were folded into the Campbell (2018) CTD database, which has been further augmented with the data collected by the ongoing GWA projects. These observations are preliminary and will be the focus of additional analyses in the future.

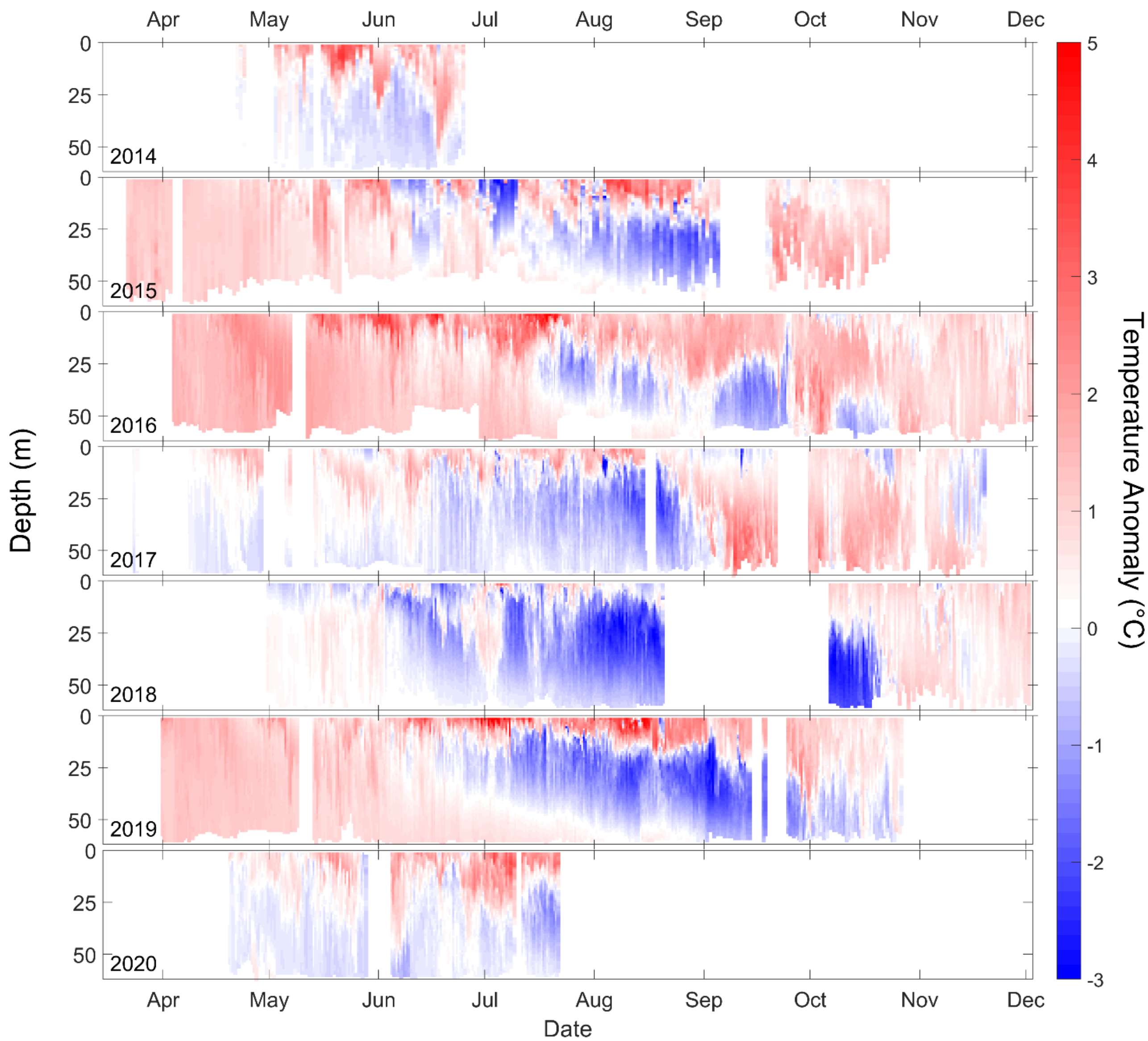

Figure 7. Temperature anomaly time series at the PWS profiler site, 2014-2020. Temperatures were averaged into 1 m bins and converted into anomalies using the method described in Campbell (2018).

An *in* situ plankton camera was developed for the profiler in 2016, in collaboration with Jules Jaffe and Paul Roberts at the Scripps Institution of Oceanography, with funding from the North Pacific Research Board (NPRB). The camera system consists of a 12 MP camera and a 99.5 mm 0.114X telecentric lens, along with darkfield illumination produced by an in-line ring/condenser lens system. The system images a volume of ~450 ml, and, operating at 4Hz during the 30 cm s^{-1} ascent of the profiler, images ~360 liters of water per profile. More than 4 million images of individual plankters have been collected during the deployments done since 2016. A subset of almost 2 x 10^4 images was manually identified into 43 unique classes, and a hybrid convolutional neural network (CNN) classifier has been developed and trained to identify the images (Campbell et al. 2020). The classifier was then used on the entire image set to examine the annual cycles in the more common plankton taxa in PWS at a much finer resolution than done previously (depths in centimeters, twice daily profiles), and showed previously unobserved annual cycles in abundance and depth distributions, that have been undescribed in several species. For instance, observations of large copepods (Fig. 8) show that the large calanoids *Neocalanus* and *Calanus* were present near surface during spring as would be expected (Cooney et al. 2001b, Eslinger et al. 2001), while the depth range of *Metridia* changes over the course of the year. *Metridia* undergoes daily diel migrations (Hays et al. 2001), and the shift in depth range may be related to changes in solar illumination over the course of the year. The vertical distribution of *Metridia* also appears to match the subsurface chl-a maximum during the summer months (e.g., compare the *Metridia* distribution in 2019 in the bottom right panel of Fig. 8 with the chlorophyll-a distribution in 2019 in Fig. 6).

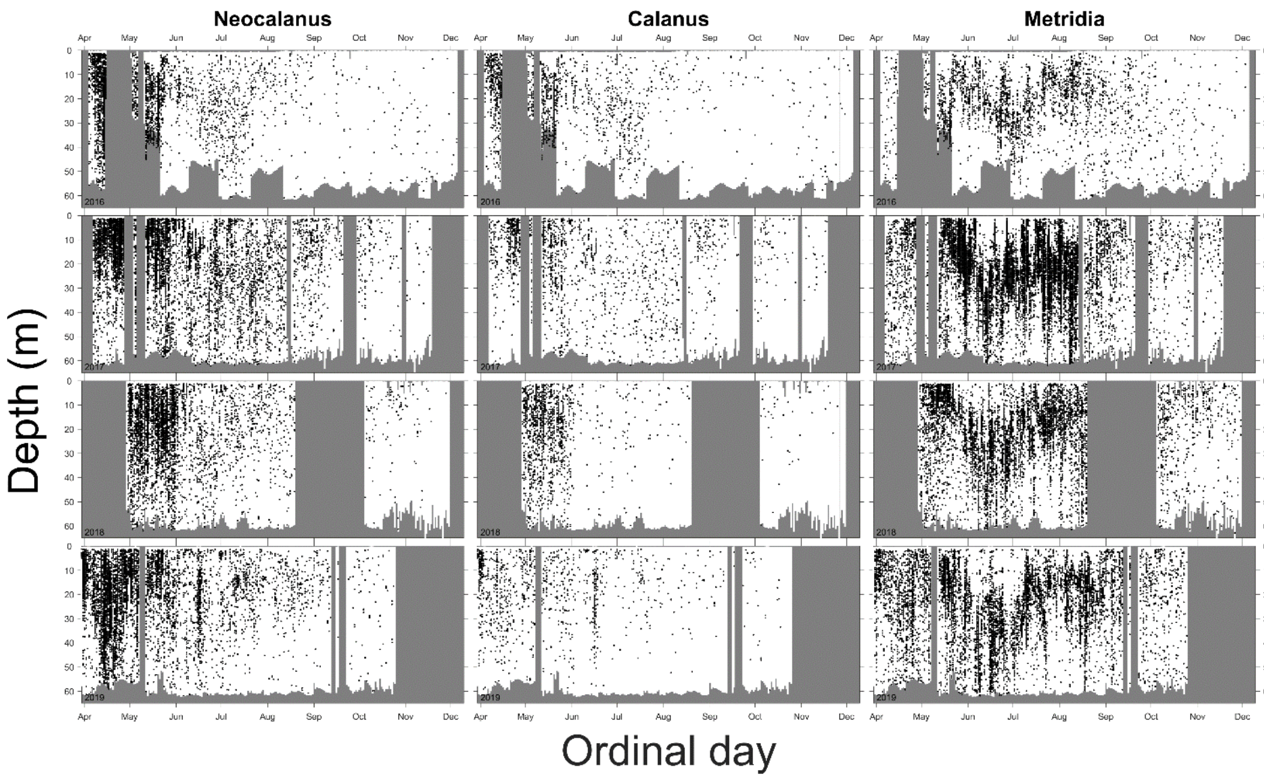

Figure 8. Depth and time distribution of images collected by the plankton camera system that were identified as large copepod species by the convolutional neural network classifier, including *Neocalanus* (left column), *Calanus* (center column) and *Metridia* (right column). Each year of deployment is presented row-wise (top row: 2016, bottom row: 2019). Images were probability filtered as described by Campbell et al. (2020) to only include high probability images (images identified by the classifier as >95% probability that they were correctly identified). Each point thus represents the time/depth position of an individual plankter of the given taxa. Time accuracy is very high (to the nearest millisecond), and depth accuracy is approximately ± 2.5 cm. Grey regions indicate times/depths with no data.

Distributions of some of the more common non-copepod taxa (Fig. 9) also show some interesting patterns, with *Limacina* pteropods and *Oikopleura* larvaceans showing episodic short-term blooms (duration of one or two weeks) and some consistent year-to-year patterns in depth distributions. *Pleurobranchia* ctenophores appear to have a broad depth distribution in spring and autumn, but a narrower near-surface distribution during summer. These individual-level observations provide an unprecedented look into the lifestyles of those groups that has not been possible with more traditional net tows. A manuscript describing the fine scale distributions of plankton taxa in PWS based on these data is in progress.

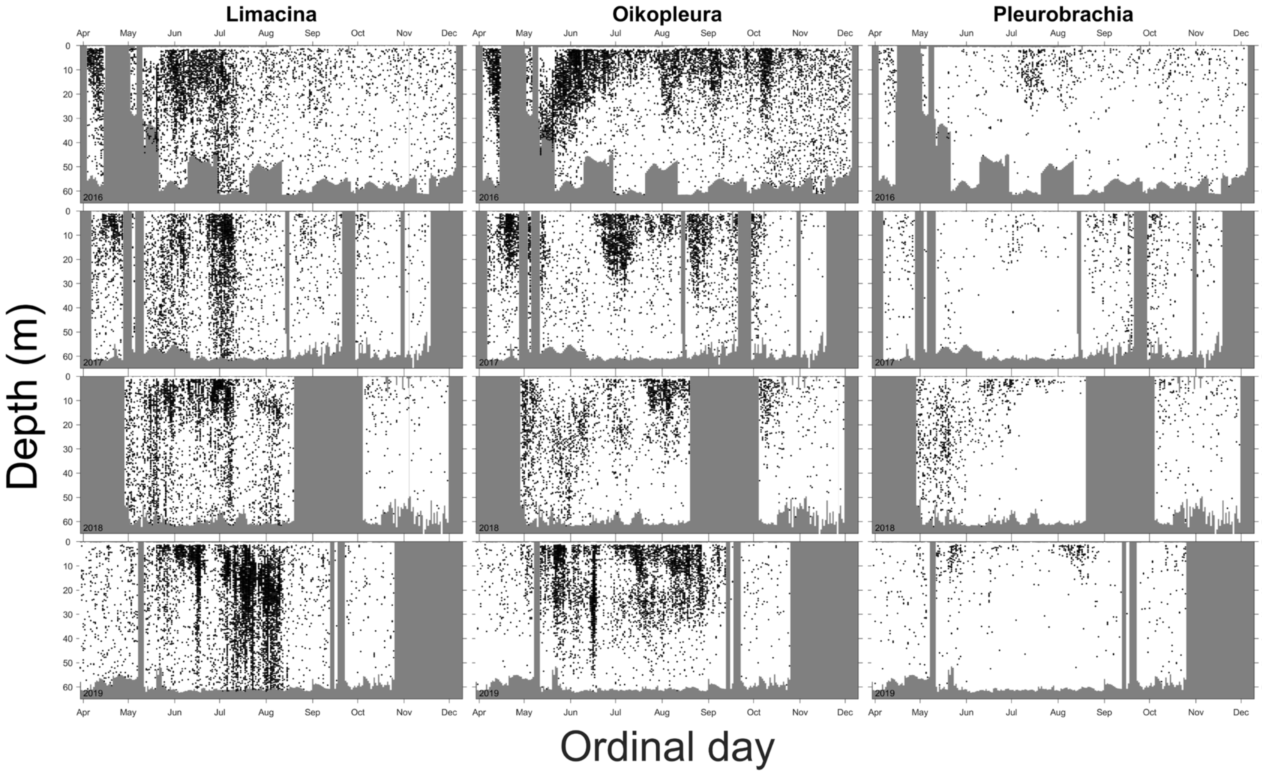

Figure 9. Depth and time distribution of images collected by the plankton camera system that were identified as some of the more common non-copepod taxa by the convolutional neural network classifier, including *Limacina helicina* (left column), *Oikopleura* sp. (center column) and *Pleurobrachia* (right column). Years are presented row-wise, and the data selection was the same as described for Fig. 8.

There are no major changes to sampling expected for this project in FY21.

<u>COVID-19 pandemic related disruptions to this project</u>

The first cruise of the year, the joint oceanography-seabird survey, was done in late February/early March as planned. The PWS Science Center (PWSSC) closed its facility in response to state-mandated COVID-19 shutdowns in March and working from home was mandated for much of March and April. The planned spring bloom cruise in late March/early April was delayed by those shutdowns and was conducted in late April after PWSSC had state-approved mitigation plans in place. The shutdowns also impacted other non-GWA projects which had cascading effects on this project (i.e., loss of PI and technician time). The post-bloom cruise was conducted in June, more or less on schedule, and the remaining cruises in 2020 should proceed as planned if there are no changes in the State of Alaska health mandates.

All laboratory work also ceased as a result of the shutdown in March. With the transition to the State of Alaska reopening plan in late May, the PWSSC facility has been partially opened, though a large proportion of the staff still work from home. Access to the laboratory is now scheduled, to prevent overlapping by staff in the same space, which has reduced the amount of time that can be spent on the samples collected by this project (a fume hood is required to handle the samples, it must be done in the lab). Chlorophyll-a samples will be analyzed and posted to the workspace on time. Processing of the 2019 zooplankton samples is proceeding at a reduced rate, and those data may not be fully available by the end of the year, it will depend on availability of the lab.

2. PROJECT STATUS OF SCHEDULED ACCOMPLISHMENTS

A. Project Milestones and Tasks

Table 1. This table breaks down project deliverables and their status into milestones and task progress by fiscal year and quarter, beginning February 1, 2017. C = completed, X = planned or not completed, V = cancelled due to COVID-19, P = partially completed, due to constraints of COVID-19. Fiscal year quarters: 1 = Feb 1 – April 30; 2 = May 1 – July 31; 3 = Aug. 1 – Oct. 31; 4 = Nov. 1 – Jan. 31.

Milestone/Task	FY17				FY18				FY19				FY20				FY21			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Milestone1: Surveys																				
Vessel surveys	C	C	C	C	C	C	C	C	C	C	C	C	C	C	X	X	X	X	X	X
Sample analysis	C	C	C	C	C	C	C	C	C	C	C	C	P	P	X	X	X	X	X	X
Data available online					C				C				C				X			
Milestone 2: Profiling mooring																				
Mooring deployed	C	C	C	C	C	C	C	C	C	C	C	C	X	C	X	X	X	X	X	X
Service/calibration				C	C			C	C			C	C			X	X			
Milestone 3: Reporting																				
Annual Reports					C				C				C				X			
Annual PI meeting				C				C				C				X				X
FY Work Plan (DPD)			C				C				C				C					

In addition to the primary project deliverables in Table 1, during the past year we contributed to three chapters in the GWA Long-Term Monitoring Program Draft Synthesis report, published one new paper in ICES Journal of Marine Science, began preparing four new papers for submission to peer reviewed journals, and contributed one outreach article to Delta Sound Connections (see Section 7). We anticipate completing FY20 and FY21 milestones and tasks as planned.

B. Explanation for not completing any planned milestones and tasks

As outlined above, one cruise was delayed, and sample analysis may be delayed because of COVID-19 health mandate restrictions.

C. Justification for new milestones/tasks

No new milestones/tasks proposed.

3. PROJECT COORDINATION AND COLLABORATION

A. Within an EVOSTC-funded Program

Gulf Watch Alaska

This project links with the Lower Cook Inlet/Kachemak Bay long term monitoring effort: plankton samples collected in Lower Cook Inlet/Kachemak Bay (project 20120114-J) are analyzed at the PWSSC under this project. We have also collaborated with the Holderied group on poster presentations and a manuscript on zooplankton distributions that is nearly complete. The data collected will also be of use to projects under the Nearshore (particularly in areas of overlap, such as Whale Bay) and Pelagic components by providing climatic context to their studies. Campbell is collaborating with Rob Suryan (project 20120114-A), Dan Monson (project 20120114-H), and Mayumi Arimitsu (project 20120114-C) and contributing data and analyses to the synthesis manuscripts. Joint cruises with a bird observer from the seabird abundance in fall and winter project (20120114-E) are done in winter and autumn. Arimitsu's project cancelled its spring and summer cruises due to the COVID-10 pandemic; Campbell has been working with aerial survey staff to ground truth their observations and collecting forage fish for energetics for her project (20120114-C).

Herring Research and Monitoring

This project links directly with the Herring Research and Monitoring (HRM) program by providing a bottom up context for the work on herring in PWS. Plankton samples have been collected and sent to Dr. Paul Hershberger for herring disease studies (project 20120111-E). Campbell has collaborated with Dr. David McGowan, a post-doctoral researcher working under the HRM program looking into interannual variability in herring spawning in PWS (project 20120111-C). Deployment of an acoustic receiver on the profiling mooring for the annual herring migration cycle project (project 20120111-B) began in 2019.

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. With Other EVOSTC-funded Projects

This project will coordinate with other *Exxon Valdez* Oil Spill Trustee Council (EVOSTC)-funded projects as appropriate by providing data, discussing the relevance and interpretation of data, and collaborating on reports and publications.

C. With Trustee or Management Agencies

Plankton samples have been regularly sent to Paul Hershberger of the U.S. Geological Survey (USGS) Marrowstone Marine Field Station to test for the presence of *Ichthyophonus* life stages. A proposal to add a discrete water sampler to the profiler is in preparation with John Crusius (USGS, University of Washington) and Amy Mueller (Northeastern). A proposal to leverage GWA observations in the vicinity of tidewater glaciers is also being developed with Shad O'Neel (USGS, Alaska Science Center) and Ellen Enderlin (Boise State). Campbell is a co-investigator on a project funded by the NPRB in 2018 to add phytoplankton, fish, and shellfish sampling to this GWA project. Samples are being sent to Xiuning Du (Oregon State University, Hatfield Marine Science Center) and Steve Kibler (NOAA Beaufort Laboratory).

4. PROJECT DESIGN

A. Overall Project Objectives

The goal of this project is to provide environmental driver data to assess temporal and spatial changes in the marine environment in PWS. The data will be depth-specific (water column stability is important to ecosystem productivity), will be of sufficient frequency to capture timing changes (days to weeks), and will give an idea of spatial variability in the region. Long term environmental monitoring data will be integrated with future herring studies as well as building upon ongoing work funded by the Trustee Council. We will maintain all sampling depicted in Fig. 1. Specific objectives include:

Objective 1

Conduct regular surveys in PWS and its entrances to continue the ongoing time series of physical, biogeochemical, and biological parameters while also supporting continued herring research by maintaining the existing time series (hydrography, plankton and nutrients) at the four Sound Ecosystem Assessment bays.

Objective 2

Install and maintain an autonomous profiling mooring in PWS that will conduct frequent (at least daily) profiles of the same physical, biogeochemical, and biological parameters as the surveys, plus in situ observations of zooplankton, large phytoplankton and other particles.

B. Changes to Project Design and Objectives

There are no changes to this project's design or objectives.

5. PROJECT PERSONNEL – CHANGES AND UPDATES

No changes to personnel.

6. PROJECT BUDGET

A. Budget Forms (See GWA FY20 Budget Workbook)

Please see project budget forms compiled for the program.

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	
Travel	$1.0	$1.0	$1.0	$1.0	$1.0	$5.0	
Contractual	$43.7	$43.7	$43.7	$43.7	$43.7	$218.3	
Commodities	$11.0	$11.0	$11.0	$11.0	$11.0	$55.0	
Equipment	$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	$0.0
General Administration (9% of	$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	$300.0	$300.0	$275.0	$275.0	$275.0	$1,425.0	

B. Changes from Original Project Proposal

No changes from original proposal. Some planned work was not done during the COVID-19 shutdown period and was therefore not billed to this project at that time. This has left some unspent funds that we will work to draw down as we catch up on our work.

C. Sources of Additional Project Funding

A major refit of the profiling mooring (new communications and electronics and development of an *in situ* plankton camera) began in 2016 with support from the NPRB ($445K from FY15-FY19). That project also supported higher than average frequency sampling and maintenance visits. NPRB is also supporting observations of phytoplankton with particular reference to the paralytic shellfish poisoning dinoflagellate *Alexandrium* sp. In FY18-21 ($389K) in PWS and Kachemak Bay. Copies of the subaward agreements are provided as separate PDF files as documentation.

The following in-kind contributions are used for this project:

- Instruments used on the vessel surveys (~$100K)
- Mooring equipment used for the profiling mooring (releases, floats, acoustic Doppler current profilers, and conductivity-temperature recorders: ~$100K)
- Laboratory equipment used for nutrient, extracted chlorophyll-a, and zooplankton analyses (nutrient autoanalyzer, fluorometer, and microscopes: ~$75K)
- Storage facilities for project equipment at several sites in Cordova.
- The vessel used for the surveys is owned by the PWSSC, which allows the timing of the cruises to be very flexible, and to avoid the standby and mobilization/demobilization fees that are standard with a charter vessel. A custom heated enclosure for a bird observer on the flying bridge was fabricated in 2019, and a proposal for a more elaborate enclosure was submitted to the Alaska Ocean Observing System in 2019. The replacement cost of the vessel is approximately $400K.

7. FY17-20 PROJECT PUBLICATIONS AND PRODUCTS

Publications

Campbell, R.W. In prep. The Annual Secondary Productivity cycle in Prince William Sound measured with the Prince William Sound plankton camera. *Manuscript ~75% complete*

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

Campbell, R.W. 2018. Long term monitoring of oceanographic conditions in Prince William Sound. *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 16120114-E). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Campbell, R.W. 2018. Long term monitoring of oceanographic trends in Prince William Sound. FY17 annual report to the *Exxon Valdez* Oil Spill Trustee Council, project 17120114-G.

Campbell, R.W. 2019. Long term monitoring of oceanographic trends in Prince William Sound. FY18 annual report to the *Exxon Valdez* Oil Spill Trustee Council, project 18120114-G.

Campbell, R.W., and C.A. McKinstry. 2018. Temperature trends in the surface waters of Prince William Sound. Pp. 57-58 *in* Zador, S. and E. Yasumiishi (eds) Ecosystem Status Report 2018: Gulf of Alaska. North Pacific Fishery Management Council.

Campbell, R.W., P.L. Roberts, and J. Jaffe. In prep. The Prince William Sound Plankton Camera: a profiling in situ observatory of plankton and particulates. ICES J. Mar. Sci.

Campbell, R.W., P.L. Roberts, and J. Jaffe. In prep. The annual secondary productivity cycle in central Prince William Sound measured with the Prince William Sound Plankton Camera. Journal of Plankton Research.

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 J. Mar. Sci. doi:10.1093/icesjms/fsaa029.

Crusius, J., A.W. Schroth, J.A. Resing, J. Cullen, and R.W. Campbell. 2017. Seasonal and spatial variabilities in the northern Gulf of Alaska surface water iron concentrations driven by shelf sediment resuspension, glacial meltwater, a Yakutat eddy, and dust. Global Biogeochemical Cycles. Doi:10.1002/2016GB005493

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 Res II. Doi:10.1016/j.dsr2.2017.08.016.

McKinstry, C., R. Campbell, and K. Holderied. In prep. Influence of the 2013-2016 marine heatwave on seasonal zooplankton community structure and abundance in the lower Cook Inlet, Alaska. *Manuscript 90% complete.*

Schroth, A.W., J. Crusius, S. Gassó, C.M. Moy, N.J. Buck, J.A. Resing, and R.W. Campbell. 2017. Aleutian Low position drives dramatic inter-annual variability in atmospheric transport of glacial iron to the Gulf of Alaska. Geophys. Res. Lett. 44. Doi:10.1002/2017GL073565.

Published and updated datasets

DataONE Published Datasets

Campbell, R. W., M. McCammon, K. Holderied, and K. Hoffman. 2017. Oceanographic Conditions in Prince William Sound, CTD, Chlorophyll-a, and Zooplankton Data: 2013-2016, Gulf Watch Alaska Environmental Drivers Component. Dataset. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Research Workspace. https://doi.org/10.24431/rw1k19.

Gulf of Alaska Data Portal Datasets

Campbell, R. 2019. Oceanographic Conditions in Prince William Sound, CTD, Chlorophyll-a, and Zooplankton Data: 2017-2019, Gulf Watch Alaska Environmental Drivers Component. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Gulf of Alaska Data Portal.

Research Workspace:

Campbell, R. 2020. Oceanographic Conditions in Prince William Sound: 2019 chlorophyll and CTD data. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Gulf of Alaska Data Portal.

Presentations

Campbell, R. 2018. A profiling observatory for high resolution oceanographic, biogeochemical, and plankton observations in Prince William Sound. Alaska Marine Science Symposium, Anchorage. **Oral presentation**

Campbell, R.W. 2018. A profiling observatory for high resolution oceanographic, biogeochemical, and plankton observations in Prince William Sound. ASLO Ocean Sciences Meeting, Portland. **Poster presentation**

Campbell, R.W. 2019. The PWS plankton cam: An underwater microscope to view the zooplankton ecosystem of Prince William Sound. PWSSC Lecture series, Cordova. **Oral presentation**

Campbell, R.W., J. Jaffe, and P. Roberts. 2019. The PWS plankton cam: An *in-situ* look into the zooplankton ecosystem of Prince William Sound. Alaska Marine Science Symposium, Anchorage. **Poster presentation**

Campbell, R.W., J. Jaffe, and P. Roberts. 2019. The PWS plankton cam: An *in-situ* look into the zooplankton ecosystem of Prince William Sound. Alaska Marine Science Symposium, Anchorage. **Poster presentation**

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. **Oral presentation**

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. Alaska Marine Science Symposium, Anchorage. **Poster presentation**

Crusius, J., A.W. Schroth, S. Gasso, and R.W. Campbell. 2018. "Gap" winds through mountainous topography dominate offshore winds along the curved coastline of southern Alaska, influencing transport of dust-derived Fe as well as Fe from upwelling and eddies. ASLO Ocean Sciences Meeting, Portland. **Oral presentation**

Kibler, S., X. Du, R.W. Campbell, K. Holderied, D. Hondolero, K. Powell Schuster, R. Robinson, M. Arimitsu, and J. Piatt. 2019. NPRB 1801: Prevalence of paralytic shellfish toxins in the marine food webs of Prince William Sound and Kachemak Bay, Alaska. Alaska Marine Science Symposium, Anchorage. **Poster presentation**

Kibler, S., X. Du, R.W. Campbell, K. Holderied, D. Hondolero, K. Powell Schuster, R. Robinson, M. Arimitsu, M. and J. Piatt. 2019. NPRB 1801: Prevalence of paralytic shellfish toxins in the marine food webs of Prince William Sound and Kachemak Bay, Alaska. Alaska Marine Science Symposium, Anchorage. **Poster presentation**

Kibler, S., B. Wright, X. Du, R.W. Campbell, K. Holderied, D. Hondolero, R. Masui, C.Guo, and C. Walker. 2020. NPRB 1801 – Prevalence of paralytic shellfish toxins in the marine food web of Southcentral and Southwest Alaska: Year 1 Update. Alaska Marine Science Symposium, Anchorage. **Poster presentation**

McKinstry, C., and R.W. Campbell. 2018. Seasonal variation of zooplankton abundance and community structure in Prince William Sound, Alaska, 2009-2016. ASLO Ocean Sciences Meeting, Portland. **Poster presentation**

McKinstry, C., and R. Campbell. 2018. Zooplankton community structure and seasonal abundance in Prince William Sound. Alaska Marine Science Symposium, Anchorage. **Poster presentation**.

Mearns, A, D. Janka, P. Marloff, R. Campbell, S. Pegau, and D. Esler. 2018. Twenty-eight years of intertidal biological variability based on volunteer visits to photo sites in Western Prince William Sound. Alaska Marine Science Symposium, Anchorage. **Poster presentation**

Monson, D., K. Holderied, R. Campbell, S. Danielson, R. Hopcroft, B. Ballachey, J. Bodkin, H. Coletti, T. Dean, K. Iken, K. Kloecker, B. Konar, M. Lindeberg, B. Robinson, B. Weitzman, and R. Suryan. 2018. Congruence of intertidal and pelagic water and air temperatures during an anomalously warm period in the northern Gulf of Alaska; the "Blob" washes ashore. Alaska Marine Science Symposium, Anchorage. **Poster Presentation**

Outreach

Campbell, R. 2018. Plankton monitoring. Web page and podcast (http://pwssc.org/plankton-monitoring/). The podcast has been used by the local radio station, KCHU.

Campbell, R. 2018. Productive plankton in the world's richest waters: the role of nutrients in the annual plankton cycle. Delta Sound Connections 2019-2020. Prince William Sound Science Center (http://pwssc.org/wp-content/uploads/2018/05/DSC-2018-FINAL_WEB.pdf).

Campbell, R. 2019. Computers to identify plankton images from Prince William Sound. Delta Sound Connections 2018-2019. Prince William Sound Science Center (https://pwssc.org/wp-content/uploads/2019/05/DSC-2019_WEB.pdf)

Campbell, R.W., J. Jaffe, and P.L. Roberts. 2018. Photographing plankton. Delta Sound Connections 2018-2019. Prince William Sound Science Center (http://pwssc.org/wp-content/uploads/2018/05/DSC-2018-FINAL_WEB.pdf)

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