1. Program Number:

18120114-G

2. Project Title:

Monitoring of oceanographic conditions in PWS

3. Principal Investigator(s) Names:

Robert W. Campbell, Prince William Sound Science Center

4. Time Period Covered by the Report:

February 1, 2018-January 31, 2019

5. Date of Report:

April 1, 2019

6. Project Website (if applicable):

www.gulfwatchalaska.org

7. Summary of Work Performed:

The planned surveys of Prince William Sound (PWS) were conducted during the reporting period (Table 1), and all 12 standard stations were occupied. All CTD data collected to date have been processed, and seasonally detrended anomalies of temperature and salinity at selected depths in central PWS are shown in Figs. 1 and 2. Temperatures in central PWS have been above average since late 2013, as has been observed elsewhere in the Gulf of Alaska (see PI Hopcroft 18120114-L and PI Danielson 18120114-I reports). PWS exhibited the same warm anomaly seen throughout the Gulf with approximately the same timing, although PWS remained slightly above average into 2017, while parts, but not all (e.g., GAK1, see PI Danielson 18120114-I report), of the Gulf of Alaska appeared to be returning to an average or perhaps cooler than average state as a result of the 2017-18 La Niña. Following a downward 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 (e.g., see: https://www.ospo.noaa.gov/Products/ocean/sst/anomaly/). Salinity anomalies in central PWS were less informative and more variable, but, for the most part, have tended towards weak freshening at the surface and more saline water at depth. Those trends likely reflect signals from ice melt and enhanced deepwater renewal (the mechanisms of which are discussed in depth in Campbell 2018).

Plankton and chlorophyll-a samples were collected from all stations with no incidents. As of February 2019, plankton samples have been enumerated from the first four cruises of 2018 (analysis of Lower Cook Inlet samples will begin in Q2 of 2019), and all chlorophyll-a filters have been analyzed.

The profiler winch and winch motor were returned to Seabird in December 2017 for bearing service and to have new seals installed. Seabird did not complete the service until late April, and the profiling mooring was deployed immediately after the electronics arrived (Fig. 3). The profiler stopped checking-in in mid-August, and after retrieval it was found that the winch would only operate in one direction. The winch and electronics were immediately shipped back to Seabird for service, where technicians found that the winch controller board had burned out and a diode had failed. The repair and shipping took several weeks, and the profiler was redeployed in early October and profiled until the first week of December, after which it was retrieved and the instruments sent in for calibration. Data gaps due to slow service turnaround and electronic failures are frustrating, but given that the profiler electronics are not user serviceable, there is little that can be done beyond having a second profiler standing by. Those costs are nontrivial (~$250K) and we are looking for funding opportunities where a second profiler might be obtained.

The 2018 time series from the profiler shows the annual cycle of surface warming, with the onset of thermal and salinity stratification in late spring/early summer and the breakdown of stability in autumn. Temperature anomalies were near baseline in spring, and had switched to primarily positive by autumn. The negative temperature anomalies at depth during summer months likely reflect a shallowing of the annual mixed layer (discussed in Campbell, 2018). Although there was elevated nitrate near-surface when the profiler was deployed, nitrate was already being consumed in the surface layer when the profiler was deployed. Observations of satellite chlorophyll (Fig. 4) also suggest that the spring bloom initiated in late April. Both the profiler (Fig. 3) and satellite estimates of surface chlorophyll (Fig. 4) showed that the bloom peaked in early May. An estimate of the historical magnitude and the timing of the spring bloom shows a decline over the satellite record (Fig. 5, top panel), and that the 2018 near-surface bloom was of larger magnitude than those during the marine heat wave (i.e., "Blob") years of 2014-2017, but still comparatively low. A simple threshold method (identifying the date when surface chlorophyll exceeded 2 $\mu g\ l^{-1}$) did not show coherent shifts in the timing of bloom initiation (Fig. 5, bottom panel). Following the spring bloom, productivity was centered on the nitricline (Fig. 3), which has been observed in prior years.

A plankton camera was developed and installed on the profiler in 2016, with funding from the North Pacific Research Board. The plankton camera collected 636,596 images during the 2018 deployment, occupying just over 20 gigabytes on disk. The highest particle concentrations were during the spring bloom in late April-early May (Fig. 3, bottom panel). There were also a large number of particles in the surface mixed layer in late June-early July. Pronounced diel differences are also notable, with "banding" (i.e., alternating bright and dark coloring in adjacent profiles) evident from profile to profile, particularly in May-June and mid-July-August. The banding effect was caused by diel differences in the number of plankton in the surface layer, with more plankton observed during nighttime profiles. A manual perusal of the images suggests that the differences are largely due to calanoid copepods, particularly of the genus *Metridia*, which are known to undertake large diurnal migrations.

A great deal of time was spent in 2018 generating a training set to feed into machine vision models to automate the identification of the plankton images that have been collected. As of the time of this report, a training set of ~20,000 manually identified images in 37 different taxa 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). Accuracy on test images has been in the range of 90-95%, with most confusion in less informative classes (smaller images that tend to be blurrier). A manuscript about the camera and identification system is in preparation.

Table 1. Status of project milestones for FY18.

Deliverable/Milestone	Status
PWS Survey	Conducted 4-7 April 2018
Deploy profiling mooring	Deployed 30 April 2018
PWS Survey	Conducted 15-17 May 2018
Service mooring	Conducted 30 May 2018
PWS Survey	Conducted 19-21 June 2018
Service mooring	Conducted 2 July 2018
Service mooring	Conducted 1 August 2018
PWS Survey	Conducted 22-23 August 2018
Recover mooring	Recovered 27 August 2018
PWS Survey	Conducted 30 September-1 October 2018
Redeploy mooring	Deployed 6 October 2018
PWS Survey	Conducted 3-5 November 2018
Recover mooring	Recovered 12 December 2018
CTD Data processed	Completed January 2019
Chlorophyll samples processed	75% complete, to be completed in February
Plankton samples enumerated	Ongoing (this project and 18120114-J)

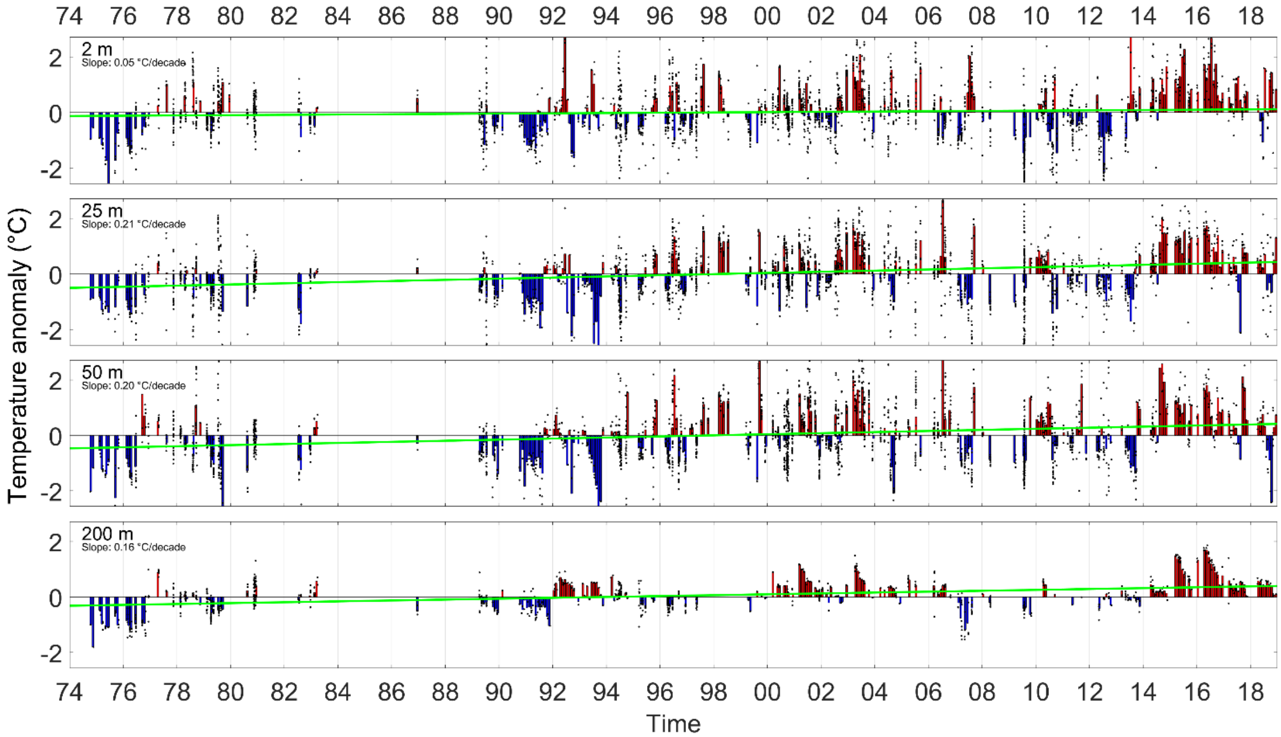

Figure 1. Temperature anomaly time series at selected depths in central Prince William Sound. Anomalies were calculated as the residual from a second order cosine fit to Julian day (for all years data) and thus represent seasonally detrended values (see Campbell, 2018 for details). Vertical bars indicate monthly average anomalies, black dots represent individual observations, and the green line indicates the linear trend. All slopes are significantly different from zero ($p<0.05$).

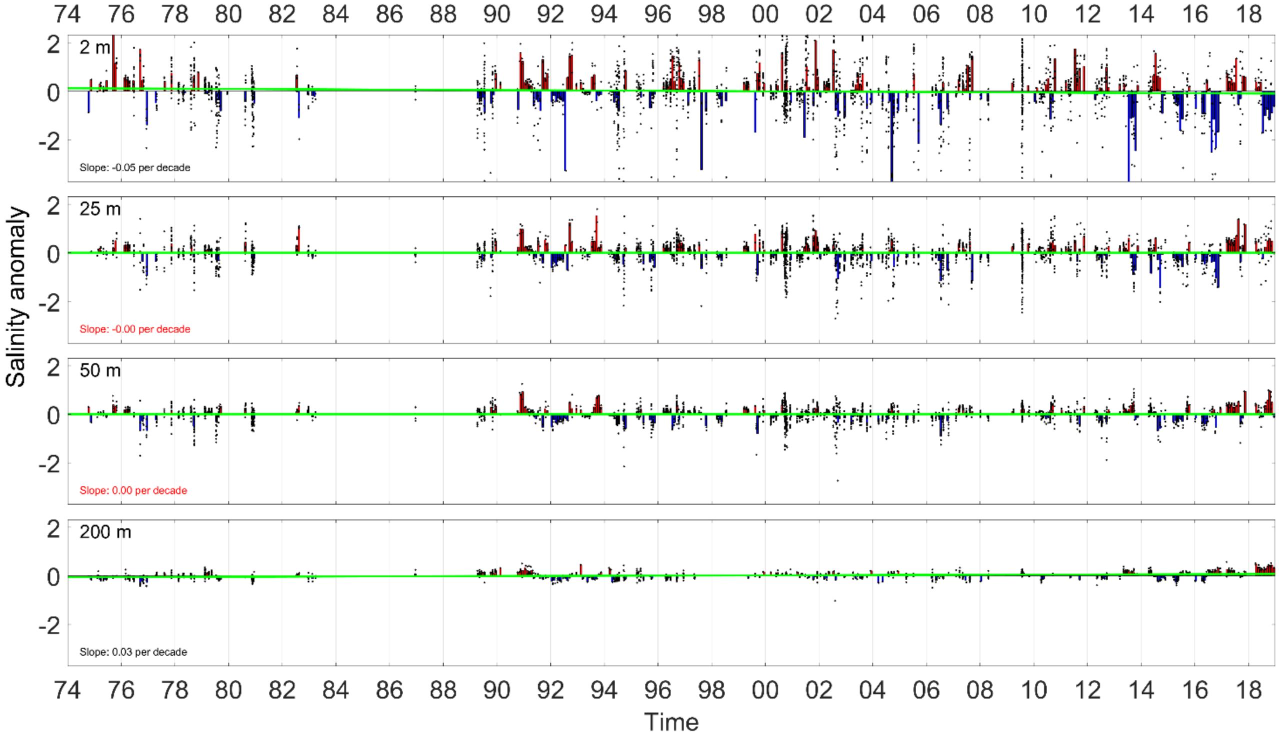

Figure 2. Salinity anomaly time series at selected depths in central Prince William Sound. Anomalies were calculated as described in Fig. 1. Red text for the slope indicates that the slope is not significantly different from zero (p>0.05).

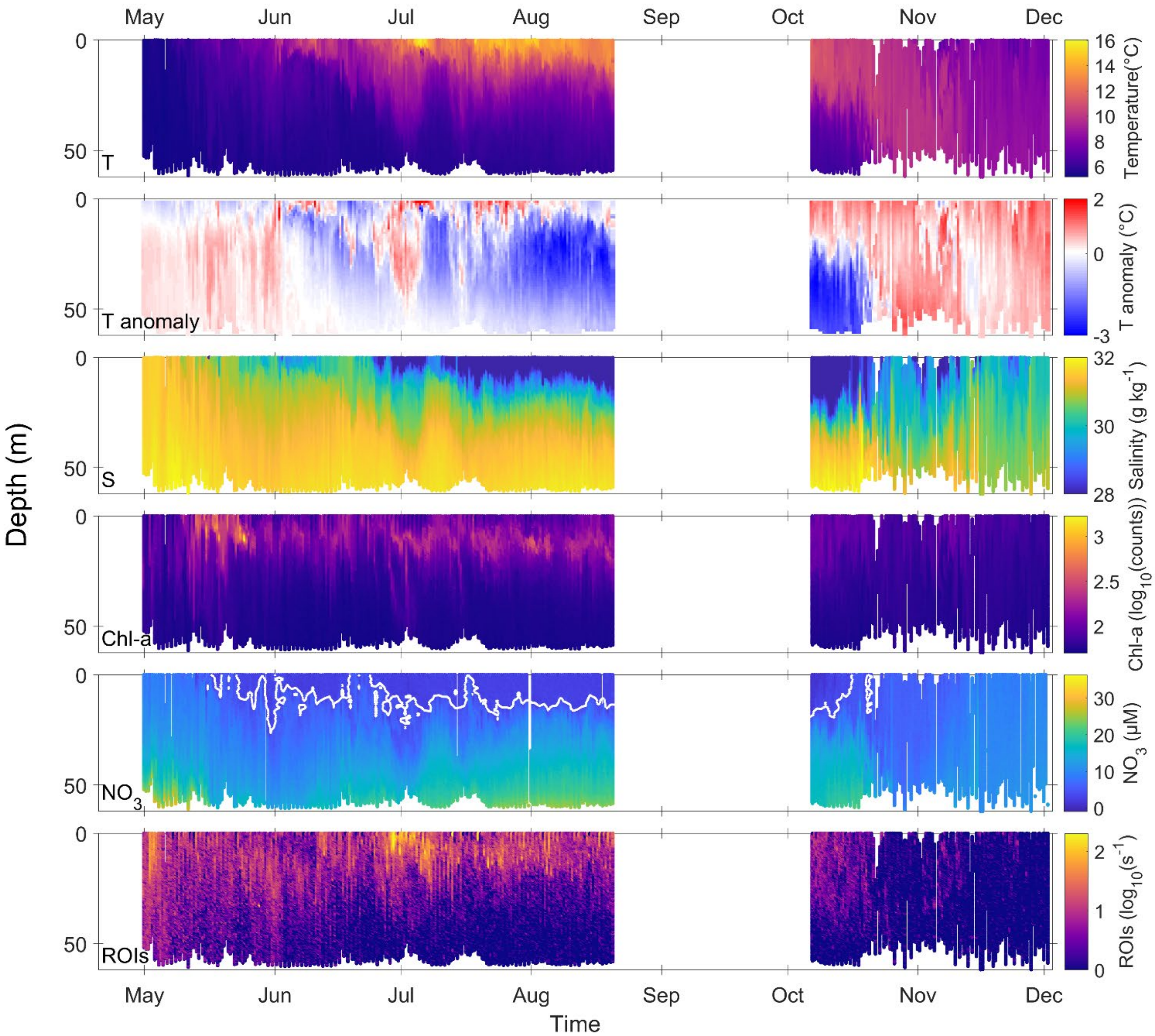

Figure 3. Time series from the 2018 deployment of the profiling mooring, including temperature (top panel), temperature anomaly (2nd panel), salinity (3rd panel) chlorophyll-a fluorescence (4th panel), nitrate concentration (5th panel), and number of plankton images captured per second (bottom panel). Each vertical line represents a single profile, and colors correspond to values of each observation. Temperature anomaly was calculated with the same method used in Fig. 1. Fluorescence is presented as digital counts from the fluorometer, and are linearly proportional to chlorophyll-a concentration. The white line in the nitrate panel (2nd from bottom) is the 4 µM contour, which generally corresponds to the subsurface chlorophyll maximum. Note that chlorophyll-a concentrations and plankton images collection rates have been log10 transformed to show finer details.

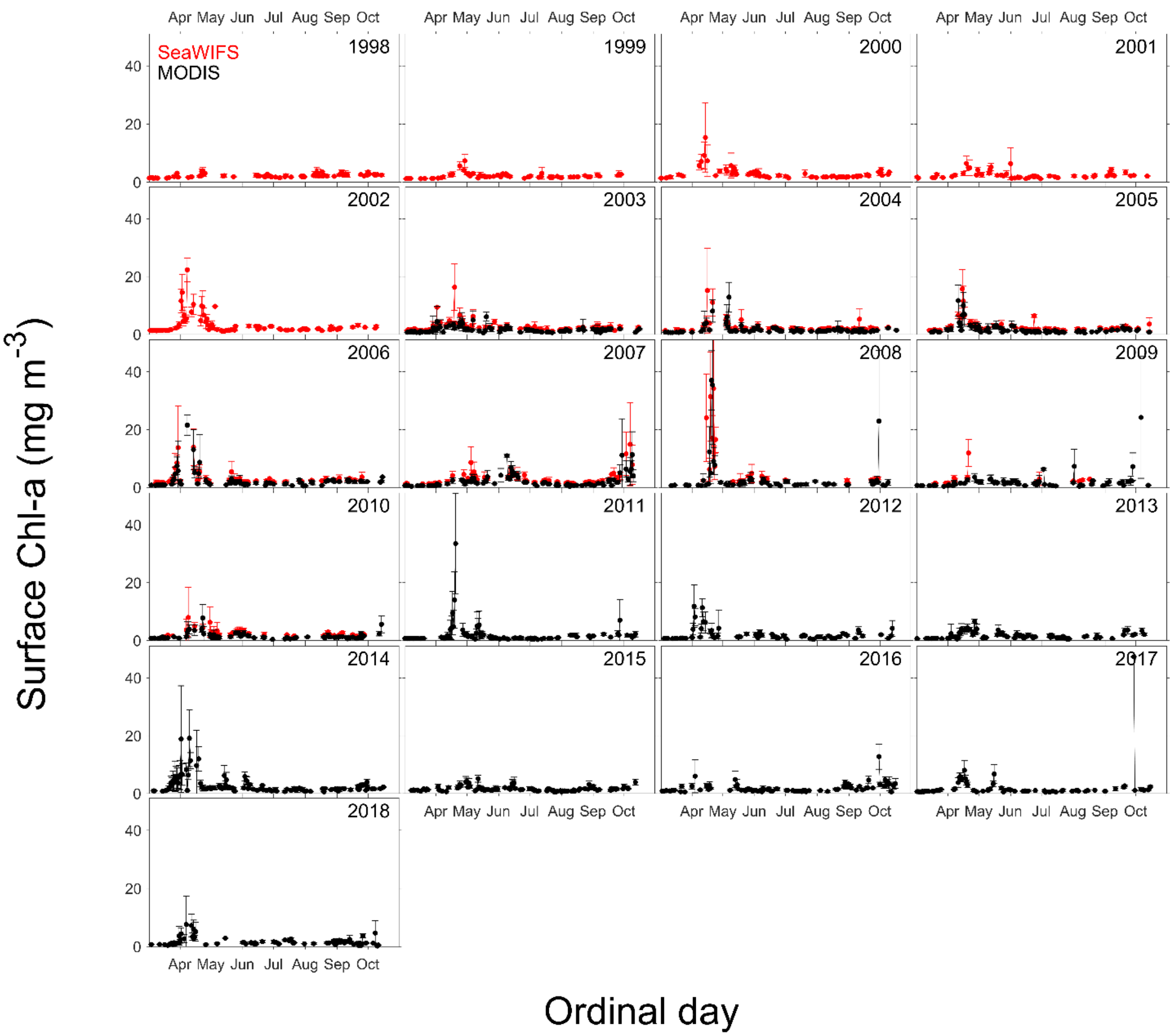

Figure 4. Time series of satellite measured surface chlorophyll concentrations (daily mean ± s.d.) in central Prince William Sound, 1998-2018. Satellite-based surface chl-a estimates were calculated from data collected by MODIS and SeaWiFS sensors and processed as L3SMI daily composites (NOAA ERDDAP products erdMH1chla1day and erdSW2018chla1day respectively) within a polygon in central Prince William Sound. The polygon was arranged to be at least one pixel from all shorelines, and three pixels from the coast of Hinchinbrook Island, where turbidity from the Copper River tends to manifest as spurious chlorophyll concentrations. All non-cloud masked pixels within the box were averaged and standard deviation calculated for each day that there were observations. The MODIS and SeaWiFS time series were compared on days that they overlapped (2003-2010), and the SeaWiFS record was found to have a slight offset that was corrected for by linear regression.

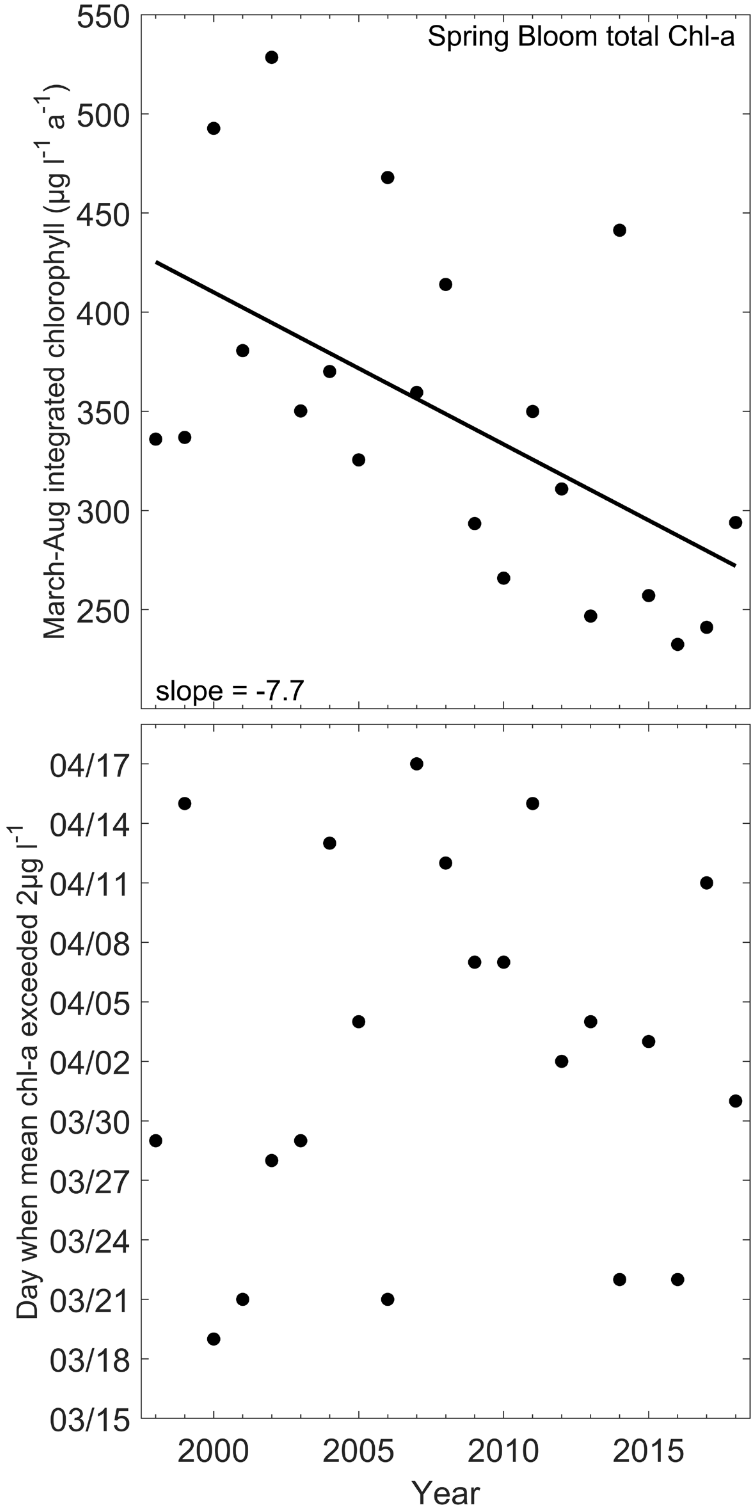

Figure 5. Time series of the magnitude (top panel) and approximate start time (bottom panel) of the satellite observed spring bloom in Prince William Sound. The overall magnitude of the bloom was estimated as the total integrated chlorophyll from March 1 to August 15 of each year, using the time series in Fig. 4 and integrating using the trapezoid rule. The start time of the bloom was estimated as the day in each year when average chl-a exceeded 2 μg l^{-1}. Other thresholds from 3-5 μg l^{-1} were also examined and gave similar results.

8. Coordination/Collaboration:

A. Projects Within a Trustee Council-funded program

1. Within the Program

All plankton samples collected as part of project 18120114-J (Long-term monitoring of oceanographic conditions in Cook Inlet/Kachemak Bay, PI Holderied) are processed and identified by this project.

Campbell contributed data and collaborated with PI Monson of the Nearshore component (project 18120114-H) and PI Suryan (Science Coordinator, project 18120114-A) on an analysis of nearshore and open water temperature records. This work is ongoing as part of the synthesis activities.

A hydrophone was deployed on the profiling mooring in 2018 to collect recordings of Killer Whale vocalizations for project 18120114-N (Long-term killer whale monitoring, PI Matkin). This collaboration has been ongoing since 2016 and has collected several terabytes of sonograms that are being analyzed to identify vocalizations by different pods. A second hydrophone in Port Etches was recovered in November 2018 by Campbell during a Gulf Watch Alaska survey. Matkin's team was not able to recover the mooring during their last survey of the year, but Campbell had on board a custom grapple developed for recovering lost moorings and was able to snag it.

2. Across Programs

a. Herring Research and Monitoring

Technicians from project 18160111-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.

b. Data Management

This project coordinates with the data management program by submitting data and preparing metadata for publication on the Gulf of Alaska Data Portal and DataONE within the timeframes required.

c. Lingering Oil

None.

B. Projects not Within a Trustee Council-funded program

None.

C. With Trustee or Management Agencies

We generally endeavor to conduct a spring cruise around the time of herring spawning when Alaska Department of Fish and Game (ADF&G) is doing their surveys (contact: Stormy Haught, ADF&G Cordova). However, herring spawn was minimal in 2018.

We contributed four new indicators to NOAA's Gulf of Alaska Ecosystem Status Report to the North Pacific Fisheries Management Council (Zador and Yasumiishi 2018).

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 September 2018. Dr. Xiuning Du (Oregon State University) is the lead PI and Campbell is a co-investigator. Phytoplankton and toxin samples are being collected for that project at all of the sites visited by this program. Campbell is also coordinating sampling efforts of larger taxa in PWS (shellfish, forage fish and salmon).

Zooplankton collections and CTD casts were done in Port Valdez for the PWS Regional Citizens' Advisory Council in May 2018, as an add-on to one of the PWS surveys. The plankton samples were enumerated with standard methods and preserved samples sent to the Geller lab at Moss Landing for genetic analysis.

Water samples were also collected in Port Fidalgo for a PWS Oil Spill Recovery Institute funded project lead by Mary Beth Leigh (University of Alaska Fairbanks) and delivered to technicians in Valdez for transport in coolers to Fairbanks. The water samples were used for a project testing the efficacy of additives designed to enhance microbial degradation of oil spills.

9. Information and Data Transfer:

A. Publications Produced During the Reporting Period

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

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. doi: 10.1016/j.dsr2.2017.08.016

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. and C.A. McKinstry. 2018. Zooplankton trends in Prince William Sound. pp. 67-70 *in* Zador, S. and E. Yasumiishi (eds) Ecosystem Status Report 2018: Gulf of Alaska. North Pacific Fishery Management Council.

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

McKinstry, C. 2018. Microscopic tourists. PWSSC Delta Sound Connections (http://pwssc.org/wp-content/uploads/2018/05/DSC-2018-FINAL_WEB.pdf)

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

Presentations

Kibler, S., Du, X., Campbell, R.W., Holderied, K., Hondolero, D., Powell Schuster, K., Robinson, R., Arimitsu, M. and J. Piatt. 2018. NPRB 1801: Prevalence of Paralytic Shellfish Toxins in the Marine Food Webs of Prince William Sound and Kachemak Bay, Alaska. Poster presentation, Alaska Marine Science Symposium, Anchorage.

Campbell, R.W. 2018. A Profiling Observatory for High Resolution Oceanographic, Biogeochemical, and Plankton Observations in Prince William Sound. Poster presentation, ASLO Ocean Sciences Meeting, Portland.

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

Outreach

Campbell, R. 2018. Productive plankton in the world's richest waters: the role of nutrients in the annual plankton cycle. Delta Sound Connections 2018-2019. Prince William Sound Science Center.

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

Data Sets and Associated Metadata that have been Uploaded to the Program's Data Portal. CTD and Chlorophyll data have been uploaded to the workspace. Zooplankton data will be uploaded when analysis has been completed.

10. Response to EVOSTC Review, Recommendations and Comments:

Science Panel Comments (EVOSTC FY18 Work Plan)**:** The Panel believes the PI is conducting important work that supports the goals of the EVOSTC. The Panel was happy to see that there are peer-reviewed publications in press and encourages the PI to keep publishing.

PI Response: I thank the Panel for their comments. Finding time to continue to work on publications is a high priority, and a top goal for the coming year. A manuscript on the profiler plankton camera is in progress, and I expect that PWS data will figure in at least two of the synthesis manuscripts.

11. Budget:

Please see provided program workbook.

Spending is slightly behind schedule, more of Campbell's time than expected was occupied by other projects in FY18, including several projects that were ending and were prioritized to be spent out. Nutrient analysis also did not begin until January 2019 because the nutrient technician was not available until then. Salary and supplies funds for those analyses will be billed in Q1 of FY19.

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	$209.0
Travel	$1.0	$1.0	$1.0	$1.0	$1.0	$5.0	$4.3
Contractual	$43.7	$43.7	$43.7	$43.7	$43.7	$218.3	$71.9
Commodities	$11.0	$11.0	$11.0	$11.0	$11.0	$55.0	$14.1
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	$299.3
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 Funds)	$300.0	$300.0	$275.0	$275.0	$275.0	$1,425.0	

LITERATURE CITED

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

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