**EVOSTC FY17-FY21 INVITATION FOR PROPOSALS**
**FY19 (YEAR 8) CONTINUING PROJECT PROPOSAL SUMMARY PAGE**

**Project Number and Title**

Gulf Watch Alaska: Environmental Drivers Component Project

**19120114-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 17, 2018

**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 (EVOSTC)-funded Sound Ecosystem Assessment (SEA) 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 will be used to enumerate zooplankton, large phytoplankton and other particles, with some taxonomic discrimination.

FY18 spring and early summer observations in PWS indicate the spring bloom was about on time, the surface layer water temperature was above average but trending towards the climatology. Some warm water copepod (southern species) are still present. We are not proposing any major changes to this project for FY19.

**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 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 2001). 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 retard 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 that new data into context with a 40-year conductivity-temperature-depth (CTD) database that has 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 changes in response to the 2013-2016 warm anomaly (aka "the Blob") over the next few years, 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

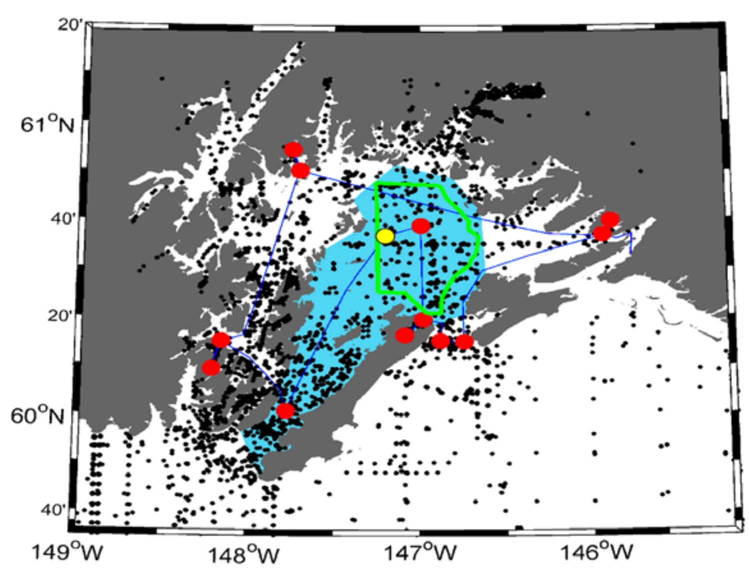


Figure 1. Prince William Sound. Black dots indicate the position of CTD casts done 1974-2016. Red dots indicate the stations visited during vessel surveys (this study), and the blue line indicates the standard vessel track. The yellow dot indicates the position of the autonomous profiling mooring. The blue area is the "central PWS" region, and was used for the determination of anomalies (see Figure 2). The green polygon is the area within which MODIS/seaWIFS chlorophyll data were averaged.

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 23,150 unique profiles dating back to 1974 (Fig. 1). Analysis of the anomalies in temperature shows a warming trend over the last 40 years at most depths (Fig. 2). The temperature trend at the surface is flat, presumably due to enhanced inputs of cold meltwater at the surface along the margin of the GOA.

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° 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. Temperature trends in FY17 suggest a return to temperatures near the long-term average, but still slightly above average (Fig. 2).

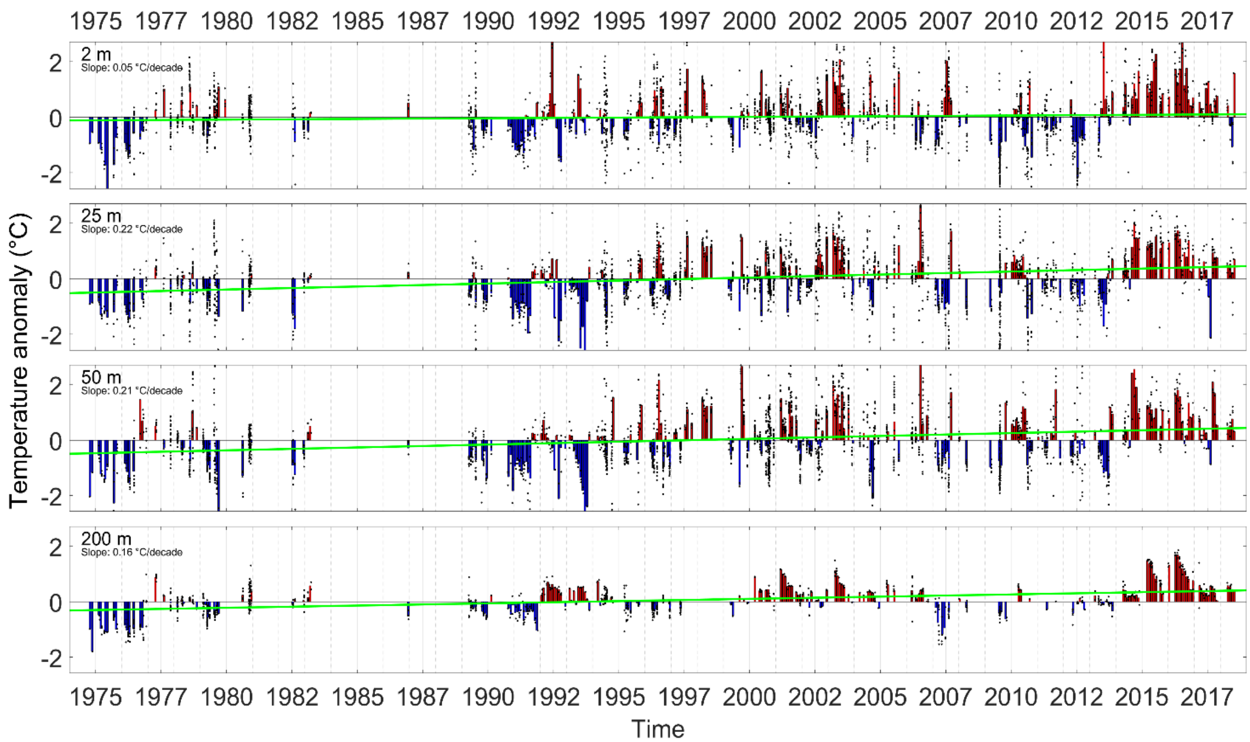


Figure 2. Temperature anomalies at four selected depths in central PWS (the blue-shaded area in Fig. 1). Anomalies were calculated as the residual to a second order cosine curve fit to all years data (to remove seasonality). Black points are observations, bars are quarterly averages, and the green line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

A time series of surface chlorophyll concentrations in central PWS was recently 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 (Fig. 3) shows that the spring phytoplankton bloom in 2014 was much earlier and stronger than average, but the spring bloom since then has been smaller. In general, the magnitude of the spring bloom has been declining over the last two decades, but there is not any indication that the timing of the bloom has changed (Fig. 4).

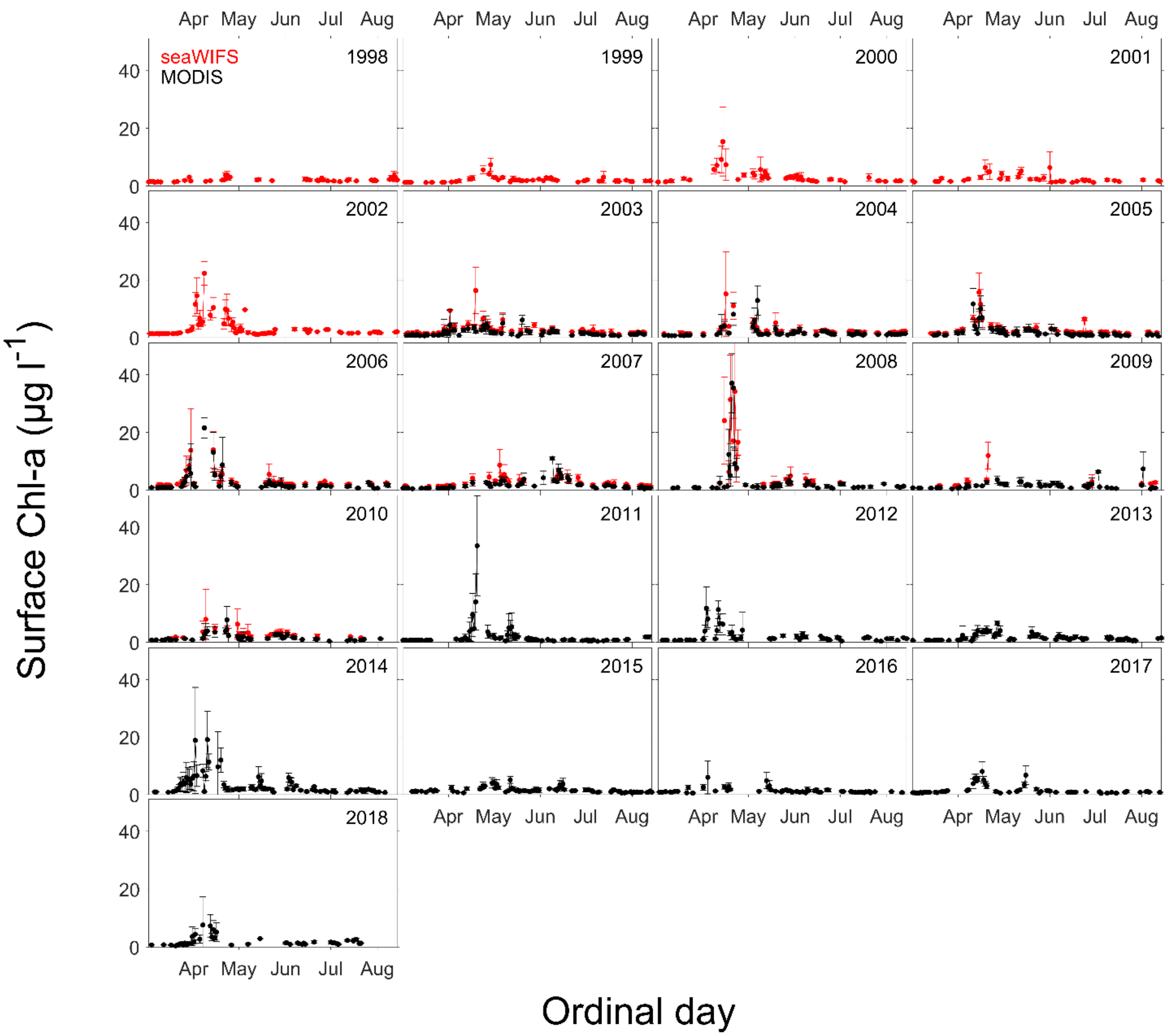


Figure 3. Surface chlorophyll-a time series in central PWS. Data are daily mean and standard deviation within non-cloud-masked pixels in central PWS (inside the green polygon in Fig. 1). The seaWIFS and MODIS data were examined for an offset between the two during years when the two time series overlapped (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 NOAA CoastWatch Program/NASA's Goddard Space Flight Center OceanColor Web (https://coastwatch.pfeg.noaa.gov/erddap/griddap/index.html; data products erdMBchla1day and erdSW2018chla1day).

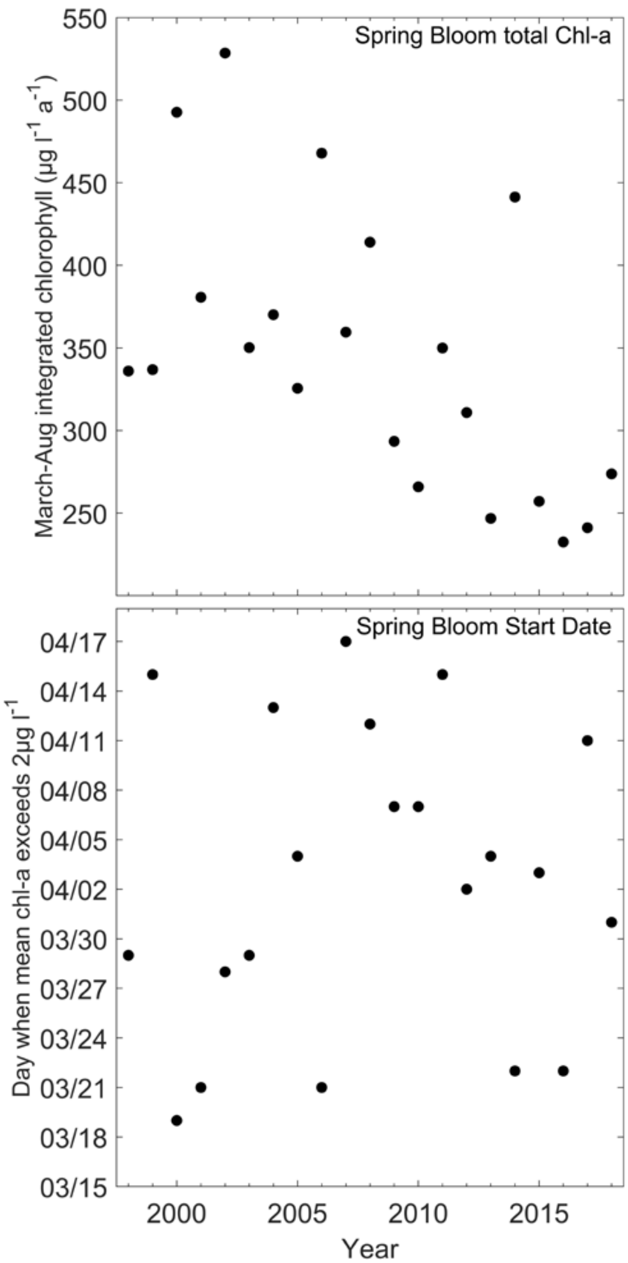


Figure 4. Estimates of the magnitude (top panel) and onset (bottom panel) of the spring bloom in central PWS (same data as figure 3). The magnitude of the bloom was estimated by numerically integrating chlorophyll concentration from March 1 to August 15 in each year using the trapezoid rule. The onset 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.

Analysis of zooplankton samples from FY17 is underway at the time of this report. Analysis of the 2010 to 2016 samples suggests that there was a shift in zooplankton taxa in PWS during the "Blob" years (Fig. 5). When copepod species are split into the "warm" and "cool" water species assemblages used by Peterson et al. (2017), it is apparent that although changes in overall zooplankton abundance have been relatively small, abundances of "warm" water copepod species increased, while that of the canonical "cool" water subarctic copepod species has decreased.

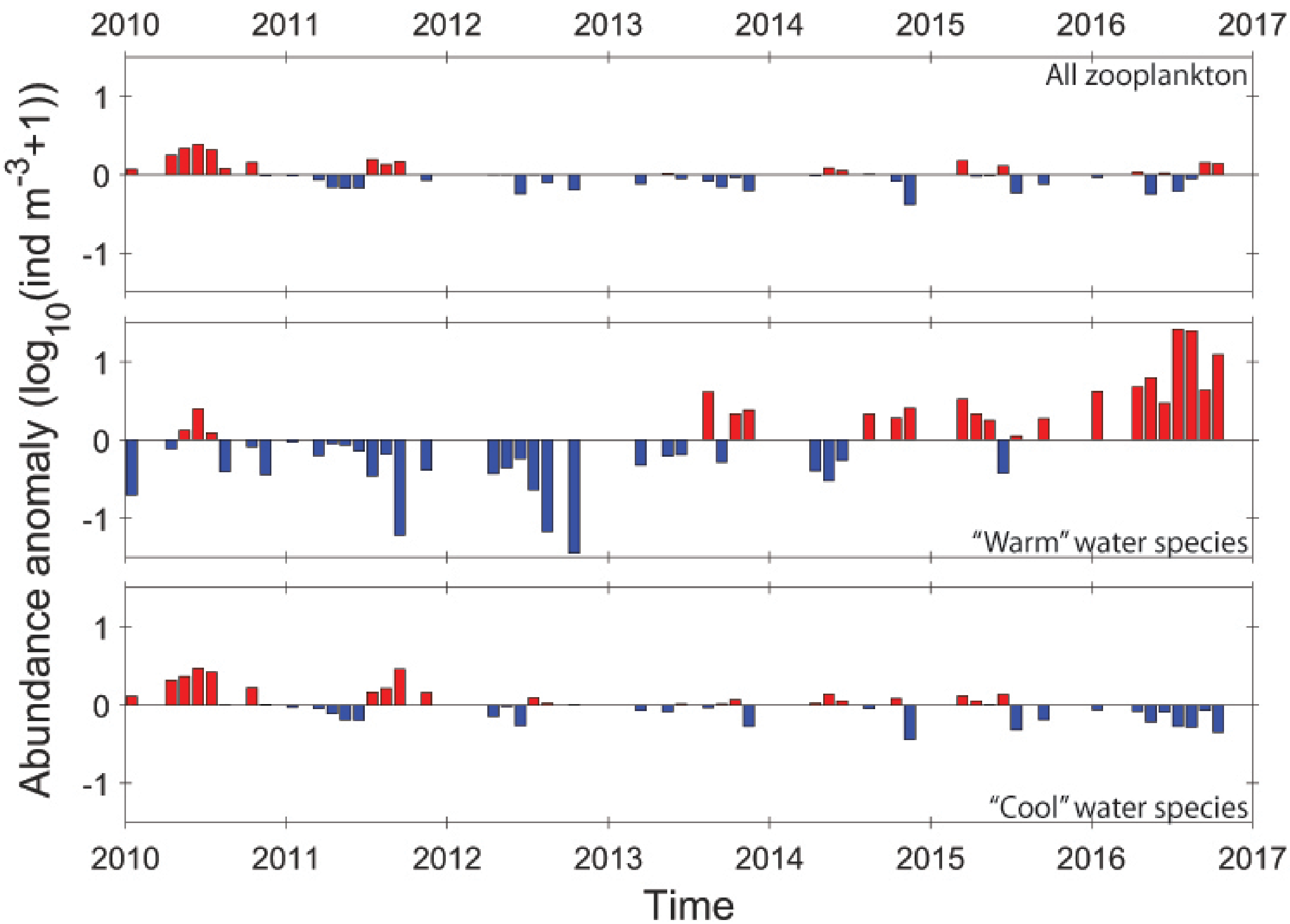


Figure 5. Time series of zooplankton anomalies in PWS, 2010-2016. Zooplankton were divided into "warm" and "cool" water copepod species per Peterson et al. (2017).

There are no major changes to sampling for this project in FY19, other than that there is new data stream now being produced by the *in situ* plankton camera on the profiler which is currently being analyzed. The system collects a prodigious amount of images (~$10^6$ per year) and convolutional neural network classifiers are in development.

## 2. PROJECT STATUS OF SCHEDULED ACCOMPLISHMENTS

### A. Project Milestones and Tasks

Table 1. Project milestone and task progress by fiscal year and quarter, beginning February 1, 2017. C = completed, X = not completed or planned. Fiscal Year Quarters: 1= Feb. 1-April 30; 2= May 1-July 31; 3= Aug. 1-Oct. 31; 4= Nov. 1-Jan 31.

| | FY17 | | | | FY18 | | | | FY19 | | | | FY20 | | | | FY21 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Milestone/**Task | 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 | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Sample analysis | C | C | C | C | C | C | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Data available online | | | | | C | | | | X | | | | X | | | | X | | | |
| **Milestone 2: Profiling mooring** | | | | | | | | | | | | | | | | | | | | |
| Mooring deployed | C | C | C | C | C | C | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Service/calibration | | | | C | C | | | X | X | | | X | X | | | X | X | | | |
| **Milestone 3: Reporting** | | | | | | | | | | | | | | | | | | | | |
| Annual Reports | | | | | C | | | | X | | | | X | | | | X | | | |
| Annual PI meeting | | | | C | | | | X | | | | X | | | | X | | | | X |
| FY Work Plan (DPD) | | | C | | | | C | | | | X | | | | X | | | | | |

### B. Explanation for not completing any planned milestones and tasks

Milestones and tasks have been completed as planned.

### 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 are analyzed at the Prince William Sound Science Center under this project. 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. The principal investigator (PI) for this project has provided data and collaborated with other GWA PIs on publications and provided platforms of opportunity for other GWA investigators. For example, a hydrophone has been deployed on the profiling mooring since 2016 to listen for marine mammal vocalizations for the GWA long-term killer whale monitoring project (Project 18120114-N).

*Herring Research and Monitoring*

This project links directly with the Herring Research and Monitoring 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. Campbell is currently collaborating with Dr. Dave McGowan, a post-doctoral researcher working under the HRM program looking into interannual variability in herring spawning in PWS.

*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 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 Marrowstone Marine Field Station to test for the presence of Ichthyophonus life stages. With John Crusius (U.S. Geological Survey, University of Washington) we are discussing the addition of a low drift oxygen sensor to the moored profiler, which may be used to infer primary productivity from oxygen generation.

## 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), of sufficient frequency to capture timing changes (weeks), and 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 SEA 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*

None.

## 5. PROJECT PERSONNEL – CHANGES AND UPDATES

No changes.

## 6. PROJECT BUDGET FOR FY19

### *A. Budget Forms (See GWA FY19 Budget Workbook)*

Please see project budget forms compiled for the program.

### *B. Changes from Original Project Proposal*

No changes from original proposal.

### *C. Sources of Additional Project Funding*

A major refit of the profiling mooring (new communications and electronics, development of an in situ plankton camera) began in 2016 with support from the North Pacific Research Board ($400K from 2015-2018). That project has also supported higher than average frequency sampling and maintenance visits.

In-kind contributions include the instruments used on the vessel surveys (~$100K), including mooring equipment used for the profiling mooring (releases, floats, acoustic Doppler current profilers, and conductivity-temperature recorders: ~$100K) and laboratory equipment used for the nutrient, extracted chlorophyll-a, and zooplankton analyses (nutrient autoanalyzer, fluorometer, and microscopes: ~$75K). The vessel used for the surveys is owned by the Prince William Sound Science Center, 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.

## 7. FY18 PROJECT PUBLICATIONS AND PRODUCTS

*Publications*

Campbell, R. W. 2018. Long term monitoring of oceanographic conditions in Prince William Sound. *Exxon Valdez* Oil Spill Trustee Council Project Final Report (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.

*Published Datasets*

**Research Workspace:** 2017 chlorophyll and CTD data uploaded to Research Workspace and undergoing QC. Data will be added to Gulf of Alaska Data Portal on schedule. 2017 zooplankton data still being processed per schedule.

*Presentations*

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

Campbell, R.W. 2018. A Profiling Observatory for High Resolution Oceanographic, Biogeochemical, and Plankton Observations in Prince William Sound. Alaska Marine Science Symposium, Anchorage.

*Outreach*

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

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

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Cooney, R.T., J.R. Allen, M.A. Bishop, D.L., Eslinger, T. Kline, et al. 2001. Ecosystem control of pink salmon (*Oncorhynchus gorbuscha*) and Pacific herring (*Clupea pallasi*) populations in Prince William Sound, Alaska. Fish. Oceanogr. 10(Suppl. 1):1-13.

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Jacob, T., J. Wahr, W.T. Pfeffer, and S. Swenson. 2012. Recent contributions of glaciers and ice caps to sea level rise. Nature 482:514-518.