FY 22-31 *PROJECT* PROPOSAL
LONG-TERM RESEARCH AND MONITORING PROGRAM

Does this proposal contain confidential information? ☐Yes ☒No

Project Number and Title

Gulf Watch Alaska Long-Term Research and Monitoring Program: Environmental Drivers Component

22120114-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 13, 2021

Project Abstract (maximum 300 words)

This project will continue physical and biological measurements that may be used to assess trends in the marine environment and bottom-up impacts on the marine ecosystems of Prince William Sound (PWS) that were highly impacted by the 1989 oil spill. Regular (~6 per year) vessel 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: in central PWS, at the entrances (Hinchinbrook Entrance and Montague Strait), and at four priority bays that were part of the *Exxon Valdez* Oil Spill Trustee Council-funded Sound Ecosystem Assessment project in the 1990s and the Herring Research and Monitoring project in the 2010s.

Additionally, an autonomous profiling mooring will be deployed each year 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 mounted on the profiler will also capture images of zooplankton, large phytoplankton and other particles to very high resolution.

EVOSTC Funding Requested* (must include 9% GA)

FY22	FY23	FY24	FY25	FY26	FY22-26 Total
$249,762	$256,008	$262,407	$268,967	$275,692	$1,312,836
FY27	**FY28**	**FY29**	**FY30**	**FY31**	**FY27-31 Total**
$282,582	$289,635	$296,888	$304,311	$311,919	$1,485,336
				FY22-31 Total	*$2,798,172*

**If the amount requested here does not match the amount on the budget form, the request on the budget form will considered to be correct.*

Non-EVOSTC Funds to be used, please include source and amount per source:

FY22	FY23	FY24	FY25	FY26	FY22-26 Total

$225,000	$225,000	$225,000	$225,000	$225,000	$1,125,000
FY27	**FY28**	**FY29**	**FY30**	**FY31**	**FY27-31 Total**
$225,000	$225,000	$225,000	$225,000	$225,000	$1,125,000
				FY22-31 Total	$2,250,000

In-kind contributions from PWS Science Center include instruments and equipment used during cruises and laboratory analyses.

1. EXECUTIVE SUMMARY (maximum ~1500 words, not including figures and tables)

The goal of this project is to continue the time series of oceanographic observations in Prince William Sound (PWS) that began in 2009 under the Gulf Watch Alaska (GWA) program and to continue to place that data into context within a 46-year conductivity-temperature-depth (CTD) database that has been assembled for the region. These data will be used to observe and describe how the marine ecosystems of the spill-effected region are changing, and to begin to address the many hypotheses for the mechanisms that are driving productivity in the region. As well as the more traditional vessel-based surveys that will return information on spatial variability, a state-of-the-art autonomous profiling mooring will continue be used to observe the evolution of the annual cycle in physical, biogeochemical, and biological parameters in central PWS at very high resolution.

A marine pelagic ecosystem is a complicated network of constantly changing trophic and biogeochemical pathways, embedded within a 3-dimensional moving fluid that evolves in both space and time. The Gulf of Alaska (GOA) ecosystem is of medium complexity (Fautin et al. 2010) but large spatial extent (order of $1.5x10^6$ km^2) and is connected to PWS through two large entrances, providing an upstream influence that is then modified within PWS in numerous ways (Cooney et al. 2001). A great deal of research has been done on the relative importance of various forcing factors, such as “top down” vs “bottom up” (e.g., Megrey et al. 2009) or climate (Francis et al. 1998). Forcing factors are moving targets (Jochum et al. 2012) and it is not instructive to pick one (Rice 2001). That said, given the conservation of mass and energy, one can expect that the amount of material and energy entering at the bottom of a food web will constrain overall ecosystem productivity. Long term observations of biogeochemical cycling and lower trophic level dynamics are thus of considerable value to the understanding of the long-term dynamics of the pelagic ecosystem in PWS, of which many injured resources are end members.

Primary productivity in the GOA and PWS is highly seasonal and thought to be mediated by the availability of light and water column stability (Henson, 2007). There is usually a large bloom each spring that depletes surface nutrients, a period of relatively low productivity through the summer months, and potentially a smaller autumn bloom as stability breaks down. The canonical mechanism for spring bloom formation is the Critical Depth Hypothesis (CDH; Sverdrup 1953), whereby bloom initiation occurs after stability reaches a critical depth and growth exceeds losses. Recent work elsewhere has suggested that the CDH does not necessarily hold, and that bloom formation may occur in winter, leading to the Dilution-Recoupling Hypothesis of Behrenfeld (2010), which explicitly includes zooplankton grazing. Neither hypothesis has been tested empirically in the GOA, likely due to lack of the necessary data.

Within PWS, variations in annual productivity have been posited to vary based on the variations 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 is 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).

There are any number of additional hypotheses for mechanisms structuring annual productivity that are more specific to the region that might be put forward, given appropriate observations. For instance, there is the role of turbidity: the waters of the margin of the GOA are quite turbid, the result of freshwater runoff containing particulates of glacial origin. The southern coast of Alaska is currently losing ice mass at some of the highest rates on earth (Jacob et al. 2012, Beamer et al. 2016), 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 surface mixed layer where productivity occurs (see below).

As part of the ongoing GWA project (project 21120114-G) that precedes this proposal, an exhaustive effort to compile all historical temperature and salinity profiles in the region was conducted (Campbell 2018). Those efforts produced a database of profiles dating back to 1974. That database has been continually combined with the data collected by the GWA program and as of January 2021 contains 24019 unique profiles from throughout the region (Fig. 1). The resulting dataset is temporally patchy and spatially variable: projects have come and gone over time, and the station locations have also varied. Some spatial aggregation is necessary to make use of the dataset (e.g., looking at “central PWS” as a single area). Analysis of the anomalies in temperature shows a warming trend over the last 40 years, and several warm stanzas in recent years (Fig. 2).

In late 2013, temperature anomalies shifted to primarily positive (Fig. 2), which echoes a pattern of warm anomalies observed GOA-wide (Bond et al. 2015). That anomaly (a marine heatwave colloquially referred to as “The Blob”) is hypothesized to have arisen because of a strong wintertime atmospheric ridge creating a persistent high pressure in the GOA, which in turn altered storm tracks and resulted in less heat flux from the surface ocean (i.e., cooling) during winter (Bond et al. 2015). Following a return to conditions near the climatological average in 2018, near surface temperature anomalies again returned to much warmer than average in 2019, with temperature anomalies even warmer than the “Blob” years. That second marine heat wave again appears to have been caused by an atmospheric ridge, one that lead to many weeks of calm weather in late summer and higher than average heat flux into the surface ocean (Amaya et al. 2020).

The recent back-to-back marine heat waves appear to be responsible for numerous changes in the marine ecosystems of the Gulf of Alaska (Suryan et al. 2021), including mortality events in birds, mammals, and seastars (Savage 2017, Piatt et al. 2020, Konar et al. 2019); larger than average blooms of toxin producing phytoplankton (Vandersea et al. 2018); declines in forage fish productivity (Arimitsu et al. 2021); and crashes in important commercial fisheries (Barbeaux et al. 2020).

Recent observations in PWS suggest that there have been large scale productivity shifts in the region since the onset of the marine heat waves. Examination of the now 22-year long time series of surface chlorophyll-a from the SeaWiFS and MODIS satellite missions in central PWS shows a trend towards lower overall primary productivity over time (Fig. 3), with among the lowest annual productivity estimates observed in the post heat wave years.

Examination of the temperature anomaly time series from the PWS profiler (Fig. 4) suggests a mechanism to explain those reductions in productivity. There are two fairly consistent patterns: a persistent warmer than average layer at the surface, and a cooler than average temperature anomaly at depth, particularly during the late spring and summer months. The surface warm layer is to be expected, but the cooler subsurface layer is somewhat paradoxical, because the deeper waters of PWS are also experiencing a warming trend (Campbell 2018). The most likely explanation for those cool anomalies is a shoaling of the seasonal mixed layer caused by increased stability driven by increased surface heat and freshwater fluxes (from melting ice). Temperature generally decreases with depth, and a shallower surface mixed layer will mean that “deep” waters will occur higher up in the water column than in climatology, and manifest as a cool anomaly. When the depth of the chlorophyll-a maximum is overlaid on top of the anomalies (black dots in Fig. 4), it is apparent that maximum chlorophyll concentrations often occurred at or near the interface of the warm and cool layers, particularly in summer. The chlorophyll maximum often occurs at the nitricline, the interface between high nitrate deep waters, and nitrogen depleted surface waters. A shallower mixed layer thus results in less overall nitrate available near surface, and less overall primary productivity to fuel the entire pelagic ecosystem.

There is also evidence of recent shifts in the zooplankton community in PWS (Fig. 5), as well as outside PWS where other environmental driver projects focus. Although the overall abundance of zooplankton has experienced only modest changes in the last decade, the post marine heatwave years showed a shift from canonical subarctic taxa (large, lipid-replete copepods) towards supertropical taxa more common in the warmer waters of the transition zone and California Current. The warm water zooplankton assemblage includes smaller taxa with modest lipid reserves that are likely poorer quality prey to planktivores, such as forage fish (notably pacific herring), which can be expected to have cascading effects up the marine food web.

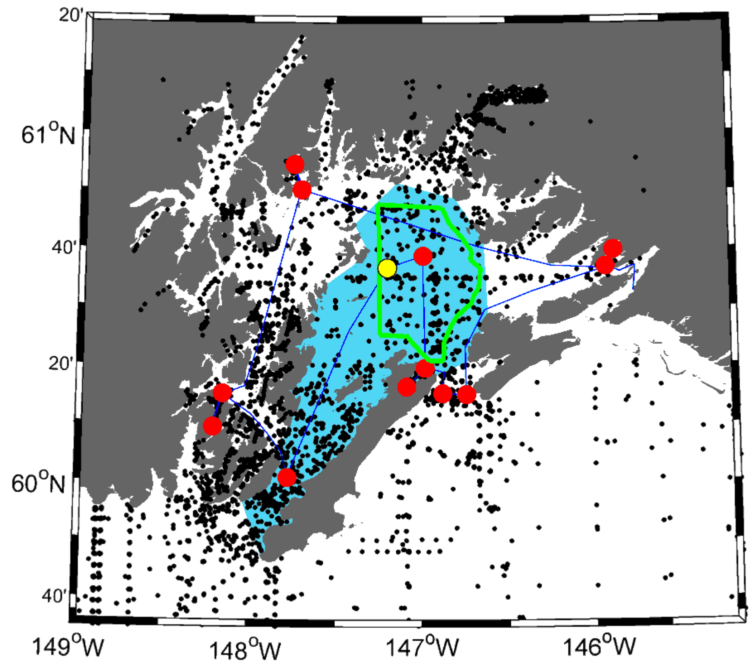

Figure 1. Prince William Sound (PWS). Black dots indicate the position of conductivity-temperature-depth casts done 1974-2020. Red dots indicate the stations visited during vessel surveys (this study), and the blue line indicates the standard vessel track. The yellow dot indicates the position of the autonomous profiling mooring. The blue area is the "central PWS" region and was used for the determination of anomalies (see Fig. 2). The green polygon is the area within which MODIS chlorophyll pixels were averaged (see Fig. 3).

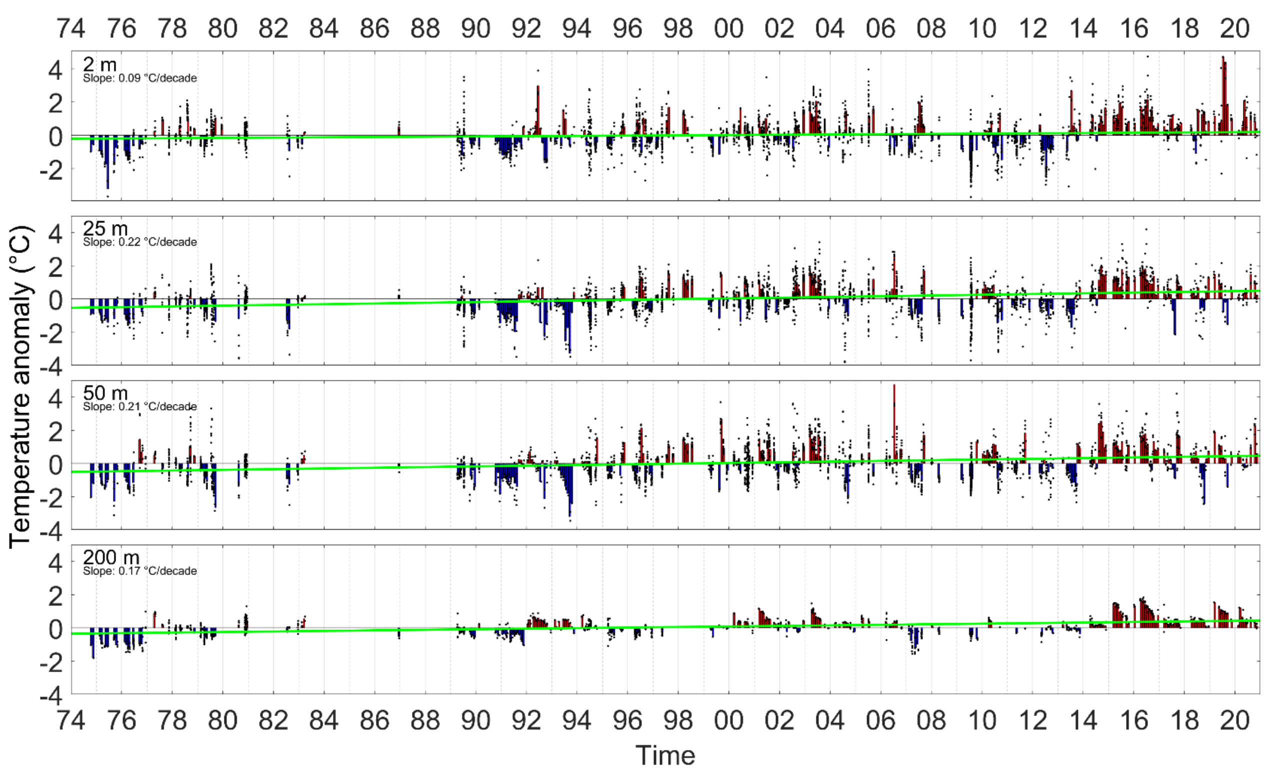

Figure 2. Temperature anomalies at four selected depths in central Prince William Sound. Anomalies were calculated as the residual to a second order cosine curve fit to all years data (to remove seasonality: Campbell, 2018). Black points are observations, bars are biweekly averages, and the green line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

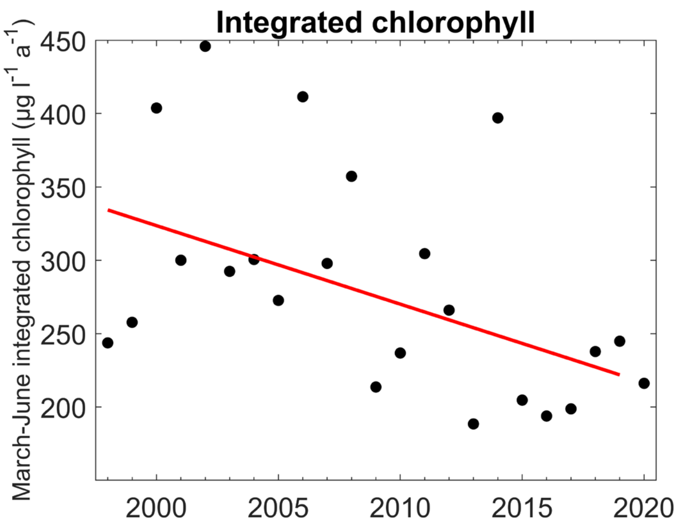

Figure 3. Estimates of the magnitude of the spring bloom in central PWS (inside the green polygon in figure 1) from surface chlorophyll-a concentrations from the SeaWiFS and MODIS satellites (NOAA Coastwatch data products SW2018chla1day and erdMH1chla1day respectively). The SeaWiFS and MODIS data were 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. The magnitude of the bloom was estimated by numerically integrating daily chlorophyll concentration from March 1 to June 31 in each year using the trapezoid rule. On dates when there was an estimate from both the SeaWiFS (adjusted for offsets) and the MODIS time series available, the midpoint was used.

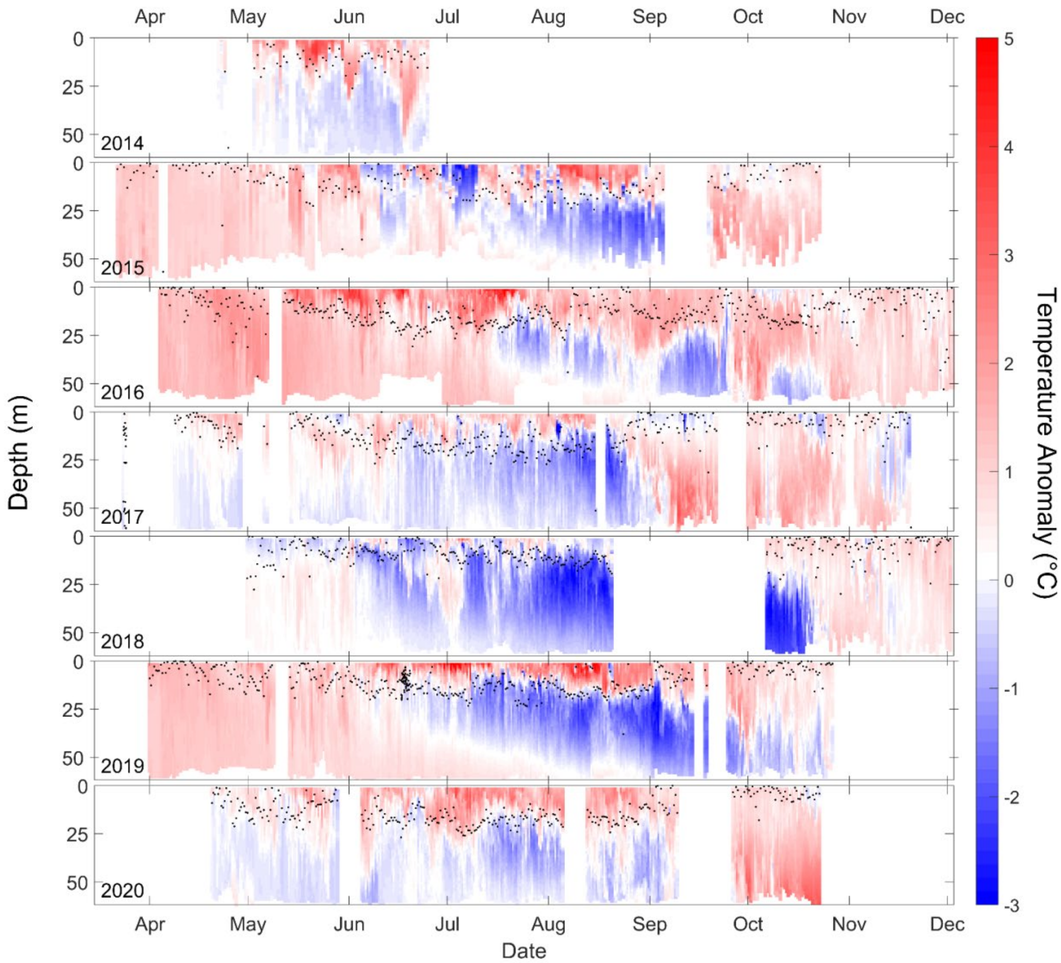

Figure 4. Temperature anomaly time series at the Prince William Sound profiler site, 2014-2020. Temperatures were averaged into 1 m bins and converted into anomalies using the method described in Campbell (2018).

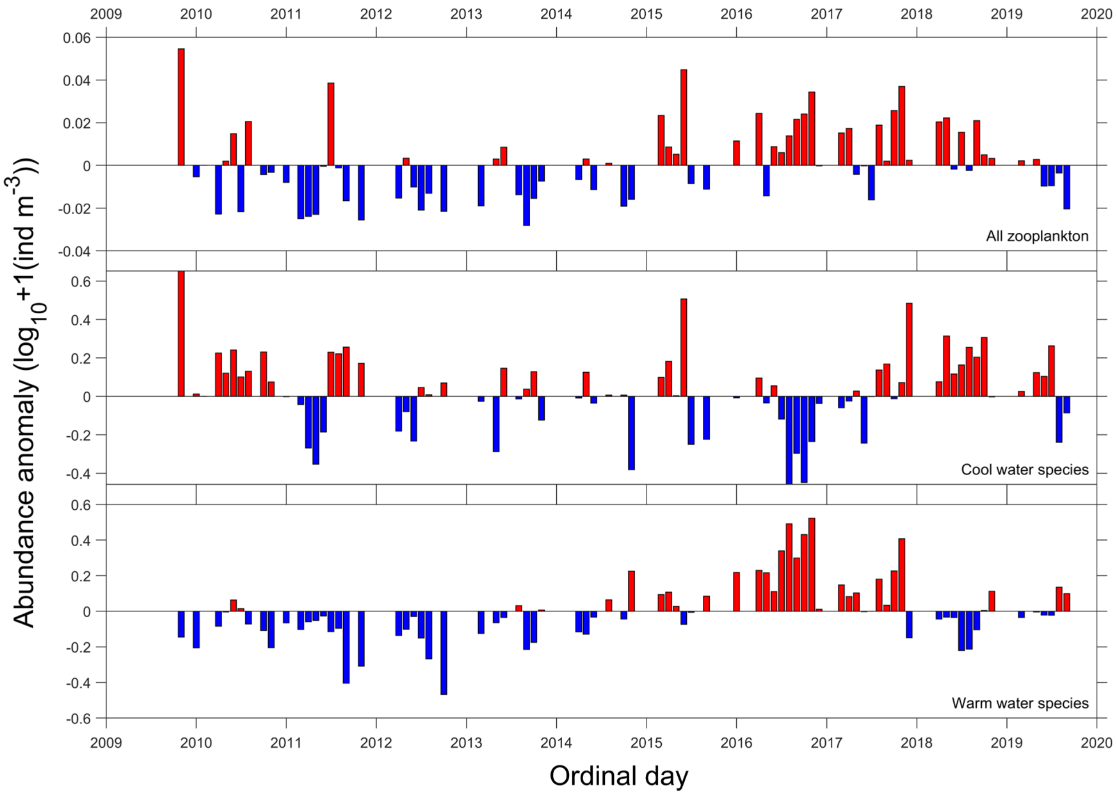

Figure 5. Time series of zooplankton anomalies in Prince William Sound, 2010-2018. Zooplankton were divided into "warm" and "cool" water copepod species per Peterson et al. (2017) and average anomalies calculated across groups per Fisher et al. (2015). Warm water species were Calanus pacificus, Clausocalanus sp., Corycaeus anglicus, Ctenocalanus vanus, Mesocalanus tenuicornis and Paracalanus parvus. Cool water species were Acartia longiremis, Calanus marshallae, Oithona similus, and Pseudocalanus spp. Abundances were log10+1 transformed prior to calculating anomalies. Note that the scaling of the ordinate varies among panels.

2. RELEVANCE TO THE INVITATION (maximum 300 words)

This project addresses the primary area of interest under the Environmenal Drivers Component. It proposes to continue the monitoring of oceanographic conditions, including water temperature, salinity, and turbidity (as well as oxygen, chlorophyll-a fluorescence and zooplankton concentrations) throughout the spill-affected area, and in the area most heavily impacted by the spill. As well as the biological studies done by this project, the data collected is of use and interest to several of the other sub-components of the project, including other Environmenal Drivers projects, and the nearshore, pelagic, and Herring Research and Monitoring (HRM) components (Campbell has been actively collaborating with several members of those projects for several years).

The decade of data already collected has been used in a climatological (Campbell 2018) and lower trophic level (McKinstry and Campbell 2018) studies, and captured many of the details of the extraordinary marine heat waves that have occurred in recent years throughout the region (Suryan et al. 2021, Arimitsu et al. 2021). The time series will continue to become more and more valuable the longer it is extended, becoming of more use for the management of resources that change over annual or longer time scales (e.g., commercial fisheries and the entire ecosystem).

3. PROJECT HISTORY (maximum 400 words)

This project began as project 10100132 of the PWS Herring Survey program (2009-2012), which included vessel surveys to the same stations occupied as part of this project and continued as Gulf Watch Alaska (GWA) project 12120114-E through 16120114-E (2012-2016) and then project 17120114-G through 21120114-G (2017-2021). Since 2009, there have been over 120 vessel sorties, spanning almost 250 sea days and covering approximately 24000 nautical miles, (almost the circumference of the earth). Over 1,200 CTD casts have been done, over 5000 water samples taken, and over 850 plankton samples collected. Over 2 terabytes of electronic data have been collected, including several million individual plankton images taken by the plankton camera on the profiler. A compilation of research accomplishments is given in Table 1.

Table 1. Summary of accomplishments by this project since 2009.

Accomplishment	Number	Details
Peer-reviewed project publications	4	Batten et al. 2016, Campbell 2018, McKinstry and Campbell 2018, Campbell et al. 2020
Peer-reviewed synthesis publications	3	Arimitsu et al. 2021, Danielson et al. (submitted), Suryan et al. 2021
Exxon Valdez Oil Spill Trustee Council (EVOSTC) final reports	2	Campbell, 2013; Campbell, 2017
EVOSTC annual reports	11	FY09-FY20
Professional conference oral presentations	2	Shi et al. 2010, Campbell 2016, Campbell 2018, Campbell et al. 2020b
Professional conference poster presentations	17	Alaska Marine Science Symposium (11), ASLO/AGU Ocean Sciences Meeting (5), Pacific Anomalies Workshop (1)
Popular articles	9	Delta Sound Connections (7), Cordova Times (1), Anchorage Press (1)
Public presentations	5	Prince William Sound (PWS) Science Center lecture series, PWS Regional Citizens' Advisory Council Science Night, PWS Natural History Symposium
Gulf Watch Alaska annual principal investigator meetings	9	

4. PROJECT DESIGN

A. Objectives and Hypotheses

The goal of this program is to deliver a monitoring program that will return useful information on temporal and spatial changes in the marine environment in PWS, at a reasonable cost. The data will be depth-specific (because water column stability is important to ecosystem productivity), of sufficient frequency to capture timing changes (changes that occur on order of weeks) and give an idea of spatial variability in the region. As well, given that

PWS herring will remain a funding priority of the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) in the next 10 years, they will be integrated with future herring studies as well as building upon ongoing work funded by the trustee council. Specific objectives include:

1. Conduct regular surveys within 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 project (SEA) bays.

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

The many specific hypotheses on how the physical environment drives and interacts with marine productivity were described in the Executive Summary above, the time series collected by this project and its predecessors is assembling the data required to test some of those hypotheses.

B. Procedural and Scientific Methods

Vessel surveys will be conducted 6 times per year, and will visit the four SEA bays (Eaglek, Simpson, Whale, and Zaikof) that have been a focus of prior EVOSTC funded research, as well as Hinchinbrook Entrance, Montague Strait, and central PWS (Fig. 1). Each station will include a CTD cast, water samples for nutrient and chlorophyll-a analysis, and a zooplankton tow (a 202 µm mesh, 60 cm diameter bongo net). Two stations will be sampled in each of the bays, one near the head where juvenile herring are more frequently encountered, and one in more open waters at the mouth of the bay where older age classes are more common. The timing of the surveys will be structured around the "productivity season" to attempt to capture the spring and autumn blooms (i.e., pre-bloom, bloom, and post-bloom). The data collected during the surveys (particularly phytoplankton abundance and nutrient concentrations) will be compared to the high frequency record in the central sound, to assess how the timing and magnitude of production events in the bays differs from the open waters of PWS. Stage composition of the copepod species collected by the plankton net will also give information on annual changes in phenology.

The Seabird SBE25plus CTD used in the surveys has in initial accuracy of ±0.001 °C and ±0.0003 S/m for temperature and salinity; and drift between annual calibrations has been on order of 0.0002 °C/year and 0.0003 PSU/month, respectively. The Wetlabs FLNTU fluorometer/turbidometer has a resolution of 0.01 µg l-1 chl-a and 0.01 NTU, and the Seabird SBE43 oxygen sensor has an accuracy of ±2% of saturation and a drift of ~3% per year. Extracted chlorophyll-a has a detection limit of 0.05µg/l. Nutrients will be measured on a Seal Analytical AA3 autoanalyzer, and detection limits for nitrate, phosphate and silicate are 0.015 µM, 0.03 µM, and 0.29 µg/l, respectively.

The autonomous profiling mooring is deployed in central PWS near Naked Island (Fig. 1). The site is the same location occupied by a surface buoy deployed during the SEA project (Eslinger et al. 2001). The mooring is an Autonomous Moored Profiler (AMP; WetLabs, Inc.). The AMP is a self-contained positively buoyant float that is capable of profiling from ~60 m to the surface, via an onboard winch that pays out and retrieves a thin (4mm UHMWPE) tether. The system is powered by an onboard 1.5 kWh battery, which allows ~60 profiles from 60 m to the surface per charge (i.e., 4 weeks of daily profiles). The instrument payload on the AMP includes a Seabird

SBE16 CTD (0.01 °C, 0.001 S/m resolution), a Wetlabs FLNTU fluorometer/turbidometer (0.01 µg l-1 chl-a and 0.01 NTU resolution), and a UV nitrate analyzer (a Satlantic SUNA: 2 µM resolution). The profiler underwent significant upgrades in early 2016, including new controller electronics and new communications hardware. An *in situ* plankton camera system was developed in collaboration with researchers at the Scripps Institution of Oceanography in 2016, it samples ~400 ml of water at 3 Hz, with a pixel resolution of ~15 µm.

C. Data Analysis and Statistical Methods

The patchiness of the long-term dataset in space and time (e.g., see Figs. 1 and 2) confounds standard time series analysis, and some spatial binning is required to produce time series that are dense enough to analyze. At present, spatially binned data (such as the blue area in Fig. 1) are seasonally detrended with a second order cosine function, anomalies determined from the residuals, and used to detect long term trends (Fig. 2). Trends have been examined with standard linear regression and more complicated nonlinear models to incorporate cyclical variations, such as the 18.6-year nodal tidal signal that arises in many geophysical and some biological datasets (e.g., Batten et al. 2016, Campbell 2018). Power analysis has not yet been conducted on this series of methods and will likely require a Monte Carlo simulation approach to be developed.

Plankton distributions will be analyzed with a set of common multivariate approaches. Species-by-station matrices will be assigned into clusters by various similarity metrics (Bray-Curtis being the most common). Following clustering, indicator species analysis (ISA) applied to the clusters returns information on the species that define the cluster groups (Legendre and Gallagher 2001). The impact of environmental parameters on species assemblages will be analyzed with Canonical Correlation Analysis, which permits reducing dimensionality and determining which environmental axes most closely relate to different zooplankton taxa. Multivariate approaches such as these are better described as descriptive (versus inferential), and power analysis is not usually applied.

The data collected by the profiling mooring results in an impressive record of the seasonal cycle of all the parameters being measured, although there have been some gaps caused by equipment failures and weather delays to service visits. The onset of seasonal stratification is captured in the temperature and salinity records, and the effect of wind events on stratification is evident. The uptake of nutrients and increased fluorescence that accompanies the growth of phytoplankton is also apparent. To better understand how the physical environment is forcing lower trophic level productivity in that area, we plan to apply the one-dimensional physical-biological model developed by Allen and Wolfe (2013). The model framework allows the impacts of various physical and biogeochemical variables to be parsed out and examined separately.

D. Description of Study Area

This study will be conducted throughout PWS, the epicenter of the spill area; the stations occupied are shown in Fig. 1 and listed in Table 2.

Table 2. Sampling stations in Prince William Sound.

Station	Latitude	Longitude
Simpson Bay head	60.67	-145.87
Simpson Bay mouth	60.61	-145.93
Hinchinbrook Entrance	60.25	-146.73
Hinchinbrook Entrance	60.25	-146.89

Station	Latitude	Longitude
Zaikof Bay head	60.27	-147.09
Zaikof Bay mouth	60.34	-146.96
Montague Strait	60.01	-147.77
Whale Bay head	60.15	-148.21
Whale Bay mouth	60.23	-148.17
Eaglek Bay head	60.93	-147.74
Eaglek Bay mouth	60.85	-147.71
Central PWS	60.58	-146.93
Profiling Mooring	60.61	-147.20

5. COORDINATION AND COLLABORATION

A. With the Alaska SeaLife Center or Prince William Sound Science Center

Dr. Campbell is an employee of the PWS Science Center (PWSSC).

B. Within the EVOSTC LTRM Program

Environmental Drivers Component

In addition to the PWS studies, all plankton samples collected as part environmental drivers studies in Cook Inlet/Kachemak Bay project (22120114-J) will be processed and identified under this project; a manuscript on the zooplankton of Kachemak Bay and lower Cook Inlet from the 2012-2018 collections was submitted in March 2021. This project's sampling complements that of the Seward Line project (2210114-L) whose focus within PWS are the deep stations of Knight Island Passage rather than the bays that are the focus of this study.

Pelagic Monitoring Component

Following advice from the Science Panel in 2018, modifications were made to the PWSSC vessel to accommodate a bird observer from project 22120114-E (fall and winter marine bird abundance). Joint cruises have been done in February-March and November since then and will continue to be done under this project. COVID-19 shutdowns of the federal labs led to the cancellation of forage fish collection activities and aerial survey validations by Arimitsu (project 22120114-C) in 2020; we did some validations for her project during our regular cruises and did some extra sorties to collect forage fish samples. We have discussed plans for assisting their sampling efforts in 2021 and will be mindful of collaboration opportunities in future.

Nearshore Monitoring Component

There are some overlaps between the Nearshore group sites and this project in southwestern PWS. Addressing the offshore/nearshore differences was addressed in the Danielson synthesis chapter, and we will continue to look for opportunities to collaborate.

Lingering Oil Monitoring Component

Because lingering oil data are collected once in a 5-year period and the oil is not currently bioavailable, we do not anticipate incorporating these data into our project. We look forward to status reports from the Lingering Oil Component.

Herring Research and Monitoring component

Technicians from project 22160111-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 has also been installed on the profiling mooring since 2019 to further extend the reach of the array. Campbell has also been collaborating with PI Bishop and PI Danielson (project 22120114-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 22120111-C) and will continue to do so in future. Efforts are made every spring to conduct a cruise during herring spawning time when HRM fieldwork is conducted, so that the data will overlap for later synthesis efforts.

Synthesis and Modeling Component

All the data collected by the project will be made available for synthesis and modeling activities. We contributed temperature and zooplankton data and participated in the drafting of three GWA science synthesis manuscripts, led by Suryan (project 20120114-A&B), Arimitsu (project 20120114-C), and Danielson (project 20120114-I) and will continue to collaborate in future.

Data Management Project

The project will continue to work with the data management project to post data to the Research Workspace and Gulf of Alaska data portal as soon as possible.

C. With Other EVOSTC-funded Projects (not within the LTRM Focus Area)

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). As the EVOSTC funds future projects outside the GWA long-term research and monitoring (LTRM) program we will evaluate their applicability to our project and coordinate as appropriate.

D. With Proposed EVOSTC Mariculture Focus Area Projects

Campbell participated in the development of the Mariculture proposal and is PI of project that expands sampling to areas in eastern PWS where intensive aquaculture development and research is occurring. We look forward to working with the EVOSTC's Mariculture Program and projects they embark on. We anticipate they will be interested in GWA LTRM datasets and we expect there will be opportunities for coordination and collaboration.

E. With Proposed EVOSTC Education and Outreach Focus Area Projects

The GWA LTRM program will develop an outreach plan that includes coordination and collaboration with the Trustee's Education and Outreach Program and projects. We look forward to participating in education and outreach opportunities where our project findings can contribute to a better understanding of the Gulf of Alaska ecosystem by the general public. We will work with the education and outreach projects to continue to develop outreach materials and educational resources. We anticipate those efforts will continue along the same lines as they have up to now, focusing on media (print, electronic, and broadcast) and outreach activities (public talks, workshops, field trips focused from "K through grey").

F. 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 every year (contact: Stormy Haught, ADF&G, Cordova), and will continue to do so.

A North Pacific Research Board (NPRB) project (1801: Prevalence of Paralytic Shellfish Toxins in the Marine Food Webs of PWS 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).

We will continue to contribute indicators to NOAA's Gulf of Alaska Ecosystem Status Report to the North Pacific Fisheries Management Council (e.g., see Zador et al. 2019) on plankton 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 Prince William Sound 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 in future.

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 the Cordova ADF&G, the plankton optimized classifier identified year 1-2 freshwater-ocean fish with 100% accuracy and 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.

G. With Native and Local Communities

The GWA LTRM program and this project are committed to involvement with local and Alaska Native communities. Our vision for this involvement will include active engagement with the Education and Outreach Focus Area (see above), program-directed engagement through the Program Management project, and project-level engagement. During the first year of the funding cycle (FY22), the GWA LTRM program will reach out to local communities and Alaska Native organizations in the spill affected area to ask what engagement they would like from us and develop an approach that invites involvement of PIs from each project, including this one. Our intent as a program is to provide effective and meaningful community involvement that complements the work of the Education and Outreach Focus Area and allows communities to engage directly with scientists based on local interests.

In addition, this project will continue engaging with local communities as we have during the first 10 years of the program, including regular outreach activities done online (for the foreseeable future) and in person, including activities such as public presentations, podcasts and radio spots and plain language publications.

As well, water samples for measurement of carbonate chemistry will be taken during the vessel surveys and sent to the analysis facility at the Alutiiq Pride Shellfish Hatchery in Seward (owned and operated by the Chugach Regional Resource Division, a coalition of several Native villages in the Chugach region). Their observations will assist other researchers in tracking the impacts of Ocean Acidification in PWS. This collaboration began in 2016 on the predecessor project to this proposal.

6. DELIVERABLES

This project will produce peer-reviewed scientific publications, presentations at scientific meetings and general presentations to the public. Predecessor projects have been featured in print (Cordova Times, Anchorage Press), and project staff have appeared on television (KTVU interview, Hunt Masters, Coast Guard Alaska) and films produced by the PWS Science Center. We will continue to produce meaningful output as outreach opportunities present themselves. All data collected will be made available through the Gulf of Alaska data portal and DataONE as DOI-referenced datasets.

7. PROJECT STATUS OF SCHEDULED ACCOMPLISHMENTS

Project milestones and tasks by fiscal year and quarter, beginning February 1, 2022. 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	FY22				FY23				FY24				FY25				FY26			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Task 1: Surveys																				
Vessel Surveys	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sample analysis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Task 2: Profiling mooring																				
Mooring deployed	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Service/calibration				X	X			X	X			X	X			X	X			X
Reporting																				
Annual reports					X				X				X				X			
Deliverables																				
Peer reviewed paper				X								X								X
Data posted online					X				X				X				X			

Milestone/Task	FY27				FY28				FY29				FY30				FY31			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Task 1: Surveys																				
Vessel Surveys	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sample analysis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Task 2: Profiling mooring																				

Milestone/Task	FY27				FY28				FY29				FY30				FY31			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Mooring deployed	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Service/calibration				X	X			X	X			X	X			X	X			X
Reporting																				
Annual reports					X				X				X				X			
Final report																				X
Deliverables																				
Peer reviewed paper				X								X								X
Data posted online																				

8. Budget

A. Budget Forms (Attach)

Please see Gulf Watch Alaska Long-Term Research and Monitoring workbook.

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

Budget Category:		Proposed FY 27	Proposed FY 28	Proposed FY 29	Proposed FY 30	Proposed FY 31	5- YR TOTAL PROPOSED	ACTUAL CUMULATIVE	TEN YEAR TOTAL
Personnel		$187,583	$192,272	$197,079	$202,006	$207,056	$985,997		$1,857,474
Travel		$2,256	$2,301	$2,370	$2,429	$2,490	$11,847		$22,328
Contractual		$56,966	$58,391	$59,850	$61,347	$62,881	$299,435		$564,094
Commodities		$12,445	$12,756	$13,075	$13,402	$13,737	$65,415		$123,234
Equipment		$0	$0	$0	$0	$0	$0		$0
Indirect Costs Rate =	0%	$0	$0	$0	$0	$0	$0		$0
Indirect Waived									
SUBTOTAL		$259,250	$265,720	$272,374	$279,185	$286,165	$1,362,694		$2,567,130
General Administration (9% of subtotal)		$23,332	$23,915	$24,514	$25,127	$25,755	$122,642	N/A	$231,042
PROJECT TOTAL		$282,582	$289,635	$296,888	$304,311	$311,919	$1,485,336		**$2,798,172**
Other Resources (In-Kind Funds)		$225,000	$225,000	$225,000	$225,000	$225,000	$1,125,000		**$2,250,000**

B. Sources of Additional Funding

Non-EVOSTC Funds to be used, please include source and amount per source:

FY22	FY23	FY24	FY25	FY26	FY22-26 Total
$225,000	$225,000	$225,000	$225,000	$225,000	$1,125,000
FY27	**FY28**	**FY29**	**FY30**	**FY31**	**FY27-31 Total**
$225,000	$225,000	$225,000	$225,000	$225,000	$1,125,000
				FY22-31 Total	$2,250,000

In-kind contributions are reported above and include the instruments used on the vessel surveys (~$100K), mooring equipment used for the profiling mooring (releases, floats, ADCP current meters and CT recorders: ~$100K), laboratory equipment used for the nutrient, extracted chlorophyll-a, and zooplankton analyses (nutrient autoanalyzer, fluorometer and microscopes: ~$75K).

This project has a history of obtaining external funding leveraged with and complimentary to the project activities and cruises. A major refit of the profiling mooring was done in 2016 with support from the NPRB ($400K), and a design of a "profiler 2.0" is in progress with engineer colleagues at Georgia Tech (funding source TBD). A surface weather buoy that was originally deployed near the profiler mooring was developed with support from the PWS Regional Citizens' Advisory Council ($125K). Phytoplankton species composition and paralytic shellfish poison toxin sampling was added to the cruises in 2019 with support from NPRB ($114K). A proposal to develop *in situ* carbonate system sensors and expand observations to PWS and Columbia Bay was submitted 12/2020 ($304K).

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10. PROJECT PERSONNEL

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EDUCATION

Doctor of Philosophy, University of Victoria, School of Earth and Ocean Sciences (1999-2003)
Thesis: "Overwintering ecology of Neocalanus plumchrus"
Master of Science, Biology, Dalhousie University (1996-1998)
Thesis: "Reproduction of Calanus finmarchicus in the western North Atlantic: fecundity and hatching success"
Bachelor of Science (Hons), Biology, University of Toronto (1991-1996)
Thesis: "Simulation and bioenergetic modeling of Walleye (Stizostedion v. vitreum) populations"

APPOINTMENTS

2020 – present	Chief Science Officer, Prince William Sound Science Center
2007 – present	Oceanographer, Prince William Sound Science Center
2010 – present	Affiliate faculty, University of Alaska Anchorage
2004-2006	Post-doctoral researcher, University of Hamburg, Germany

RECENT RELEVANT PUBLICATIONS

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RECENT COLLABORATORS (EXCLUSIVE OF CO-AUTHORS ALREADY LISTED ABOVE)

Causey, Doug (UAA); Doroff, Angela (UAA); Gassó, Santiago (NASA); Gorman, Kristin (UAF); Heintz, Ron (NOAA, ret.); Rand, Pete (PWSSC); Sewall, Fletcher (NOAA); Sorum, Alan (PWSRCAC); Thomas, Andrew (U Maine); West, Mick (Ga. Tech)

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July 12, 2021

To: Mandy Lindeberg - NOAA, GWA-LTRM Program Lead
Shiway Wang, EVOSTC Executive Director

Re: *Letter of Commitment*

We are pleased to provide this letter of commitment for the proposed project "Long-term monitoring of oceanographic conditions in Prince William Sound", project number 22120114-G that is part of the Pelagic Component of the Gulf Watch Alaska Long-Term Research and Monitoring (GWA-LTRM) program and is led by principal investigator Robert Campbell Ph.D.

This proposal was drafted in response to the EVOSTC's FY22-31 Invitation for Proposals and subsequent request for final submission on August 13, 2021. The cost for this project over a ten-year period will be $2,250 K (without EVOSTC GA). This includes some non-EVOSTC funds that are in-kind contributions currently totaling an estimated $225K (Equipment used by the project).

This project proposal is part of the larger multi-agency GWA-LTRM program proposal package. Since 2009, the PWS oceanographic monitoring component of this package has represented a continued commitment of the successful long-term research and monitoring projects supported by the EVOSTC and various agencies and organizational investments.

Sincerely,

Katrina Hoffman, President & CEO
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