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

Proposals requesting FY22 - 31 funding are due to shiway.wang@alaska.gov and linda.kilbourne@alaska.gov by March 29, 2021. Please note that the information in your proposal and budget form will be used for funding review. Please refer to the Invitation for the specific proposal requirements for each Focus Area. The information requested in this form is in addition to the information requested in each Focus Area and by the Invitation. We may make inquiries regarding the project and proposer(s), including consulting with agencies or other parties. Project proposals may be submitted in response to only one current Invitation (FY 22-31 or FY 22-26). A project that is submitted under both Invitations may be disqualified from consideration. Please indicate below if your proposal contains confidential information.

Does this proposal contain confidential information? ☐Yes ☐No

Project Number* and Title

22220202 Continuation and expansion of ocean acidification monitoring in the Exxon Valdez Oil Spill area

Primary Investigator(s) and Affiliation(s)

Claudine Hauri, International Arctic Research Center, University of Alaska Fairbanks

Date Proposal Submitted

08/18/2021

Project Abstract (maximum 300 words)

The abstract should provide a brief and concise overview of the overall goals and hypotheses of the project and provide sufficient information for a summary review as this is the text that will be used in the public work plan and may be relied upon by the EVOSTC Public Advisory Committee and other parties.

Ocean acidification and warming are putting an additional strain on a marine ecosystem that is slowly recovering from the 1989 Exxon Valdez Oil Spill. The high latitude Gulf of Alaska ecosystem is especially vulnerable to ocean acidification and requires high-resolution in-situ observations to characterize the natural inorganic carbon variability, and monitor the progression of ocean acidification and climate change. High-resolution ocean acidification monitoring was conducted along the historic Seward Line between 2008 and 2017. Unfortunately, this effort was reduced to just 4-5 stations per cruise in 2018, terminating a time series that was starting to help us understand natural variability, local drivers, and define ocean acidification hotspots and potential impacts on the ecosystem. Here, we propose to reinstitute high-resolution ocean acidification monitoring along the Seward Line and in Prince William Sound in May, July, and September, and expand monitoring along an additional transect off Kodiak. This project will leverage already funded projects, such as the Northern Gulf of Alaska Long Term Ecological Research (NGA-LTER) program and the Gulf of Alaska Ecosystem Observatory, funded through a consortium of agencies and institutions such as the National Science Foundation (NSF), EVOSTCs Gulf Watch Program, Alaska Ocean Observing System (AOOS), North Pacific Research Board (NPRB), and The M.J. Murdock Charitable Trust. In addition to extending the temporal and geographic coverage of a critical data set, the proposed sampling plan includes the new Kodiak Line, which passes by highly productive areas near current and planned future mariculture grounds suggested to be an ocean acidification hotspot. Thus, understanding the current chemical conditions and progression of ocean acidification is of high socio-economic importance to the region. Overall, the proposed project will help to distinguish the effects of the oil spill from the effects of ocean acidification on the ecosystem and manage sensitive or injured species and resources.

EVOSTC Funding Requested (round to the nearest hundred, must include 9% GA)

FY22	FY23	FY24	FY25	FY26	FY22-26 Total
$157,100	$138,800	$120,900	$123,400	$124,900	$665,100
FY27	**FY28**	**FY29**	**FY30**	**FY31**	**FY27-31 Total**
$127,500	$129,100	$131,900	$133,500	$136,400	$658,400
				FY22-31 Total	*$1,323,500*

Non-EVOSTC Funds to be used, (round to the nearest hundred) please include source and amount per source:

FY22	FY23	FY24	FY25	FY26	FY22-26 Total
					**See "Sources of Additional Funding" for details*
FY27	**FY28**	**FY29**	**FY30**	**FY31**	**FY27-31 Total**
					**See "Sources of Additional Funding" for details*
				FY22-31 Total	**See "Sources of Additional Funding" for details*

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

Please provide a summary of the project including key hypotheses and overall goals. Describe the background and history of the problem. Include a scientific literature review that covers the most significant previous work history related to the project. Include which injured resources and services will be studied and describe how these affected resources, services and ecosystems will benefit from this project.

The 1989 Exxon Valdez Oil Spill (EVOS) put the coastal Gulf of Alaska ecosystem under unprecedented stress. While a large majority of the affected sites and species have recovered over the last 30 years, there are still areas with subsurface oil sequestered in sediment (Nixon et al., 2018), and some species have yet to fully recover (Michel et al., 2016). In addition to the oil spill, this ecosystem has been exposed to a multitude of stressors related to climate change and ocean acidification. For example, climate change has already led to a substantial increase in freshwater discharge (Neal et al. 2010; Hood et al., 2015). This has changed the salinity and nutrient load, and decreased the seawater aragonite saturation state to levels that may be harmful to shell-building organisms such as mussels and clams (Hauri et al., 2020). In addition, ocean acidification has been decreasing the aragonite saturation state and pH to levels potentially harmful to organisms (e.g. Fabry et al., 2009; Mathis et al., 2014; Hauri et al., accepted) that may still be recovering or have just recovered from oil spill. These invisible environmental stressors may have played a role in silently slowing down the recovery of the natural resources and services in the Spill Area. Overall, ocean acidification impacts disproportionately those same communities in coastal, freshwater-affected settings that were also hardest hit by the spill. Here, we seek to better understand and quantify the role of changing carbon chemistry in slowing down the recovery of the natural resources and services and help identify 1) which living marine resources might be the most vulnerable to ocean acidification, and 2) which locations might need additional monitoring efforts.

Ocean acidification in the Gulf of Alaska

Carbon dioxide concentrations in Earth's atmosphere continue to climb from their preindustrial levels of approximately 280 ppm to well over 400 ppm in recent years. Meanwhile, the oceans are absorbing approximately 25% of this carbon dioxide (CO_2), driving a fundamental shift in ocean chemistry. This process, known as ocean acidification, increases seawater concentration of CO_2 and decreases pH. It also decreases the carbonate ion (CO_3^{2-}) concentration and, as a result, the saturation state (Ω) of CaCO3 minerals, such as aragonite and calcite. Aragonite and calcite chemically dissolve when $\Omega < 1$. However, many marine calcifiers that make aragonite or calcite-based shells are sensitive to a decrease in Ω well above the thermodynamic threshold of $\Omega = 1$ (Doney et al., 2020). The Gulf of Alaska marine ecosystem is naturally low in CO_3^{2-} concentrations due to the increased solubility of CO_2 at low temperatures, ocean mixing patterns (Feely et al., 1982; Feely et al., 1988; Byrne et al., 2010), summertime upwelling of carbon-rich waters onto the shelf (Evans et al., 2013), and unique riverine and glacial inputs (Mathis et al., 2011; Evans et al., 2014; Reisdorph and Mathis, 2014). For these reasons, seawater saturation states with respect to aragonite and calcite are typically lower here than in temperate and tropical regions, putting them naturally closer to the tipping point where organisms feel stress. Indeed, aragonite undersaturated conditions have already been observed in some coastal waters of the Gulf of Alaska (Fabry et al., 2009; Evans et al., 2014).

Ocean acidification, warming, heat waves, and ocean acidification extreme events are putting an additional strain on a marine ecosystem that is slowly recovering from the 1989 Exxon Valdez Oil Spill (Laufkoetter et al., 2020, Hauri et al., 2020; Hauri et al., accepted). Our recent biogeochemical modeling study suggests that Ω_{arag} and pH have decreased by -0.07 +/- 0.003 per decade (1 STD) and -0.019 +/- 0.001 per decade, respectively, and pCO_2 has increased by 17.4 +/-1.4 µatm decade-1 ($p < 0.05$ per decade over the past 34 years (Hauri et al., accepted). The same study also found that climate driven decadal pulses could lead to sub-decadal ocean acidification extreme events with potentially far-reaching consequences for marine ecosystems. The Gulf of Alaska is home to highly productive commercial and subsistence fisheries including salmon, pollock, crab, Pacific cod, halibut, mollusks and other shellfish. Some of these abundant living marine resources are vulnerable to the effects of ocean acidification (e.g. Williams et al., 2018; Long et al., 2013) and there is evidence that ocean acidification extreme events may have already harmed Pteropods (Bednarsek et al. submitted). This is concerning because these calcifying mollusks are an important part of the diet of pink salmon (Auburn and Ignell, 2000; Daly et al., 2019), a commercially important species and key part of the food chain in the region. The biogeochemical modeling study also shows that the Gulf of Alaska chemical environment is close to harmful thresholds that can be quickly crossed via short-term disturbances. Furthermore, it is likely that the combination of climate change and ocean acidification may cause these ocean acidification extreme events to become more frequent, intense and longer in future years (Hauri et al., accepted).

In future years, ocean acidification may have a particularly negative impact on industries hardest hit by the spill such as aquaculture and salmon fisheries. Our proposed work seeks to provide a basis for both assessing potential threats and creating monitoring/prediction tools that can help these coastal communities navigate the challenges better. The Gulf of Alaska ecosystem requires increased in-situ observations to characterize the inorganic carbon chemistry variability and monitor the progression of ocean acidification and climate change. The historic Seward Line (Figures 1 and 2) was sampled extensively for dissolved inorganic carbon (DIC) and total alkalinity (TA) in May and September between 2008 and 2017. Unfortunately, this effort was reduced to less than 60 samples (4-5 stations) per cruise starting in 2018. Figure 1 shows DIC, TA, and pH along the Seward Line in spring (top) and fall (bottom). In spring, every station between GAK1 and GAK 15 was sampled (black crosses), whereas in fall, only a total of 4 stations were sampled between GAK 1 and GAK9. This comparison shows that many spatial features (including hotspots) get lost if the system is undersampled. Ocean acidification requires several decades of high-resolution monitoring in coastal environments with large natural variability (Henson et al., 2010; Carter et al., 2019; Hauri et al., accepted). Therefore, if ocean acidification monitoring in the Gulf of Alaska is not continued and expanded now, the data and the investment made between 2008 and 2017 will be irretrievably lost, inhibiting efforts to quantify the changes and impacts of ocean acidification.

Here, we propose to reinstitute high-resolution inorganic carbon monitoring along the Seward Line and in Prince William Sound in May, July, and September, and expand the monitoring along an additional transect off Kodiak. This project will leverage off already funded projects, such as the Northern Gulf of Alaska Long Term Ecological Research (NGA-LTER) program and the Gulf of Alaska Ecosystem Observatory, which were funded through a consortium of agencies and institutions such as the National Science Foundation (NSF), EVOSTCs Gulf Watch Program, Alaska Ocean Observing System (AOOS), North Pacific Research Board (NPRB), The M.J. Murdock Charitable Trust, and the University of Alaska Fairbanks (UAF). While sampling of the Seward Line and the stations in Prince William Sound is essential to continue this over a decade long effort, the transect near Kodiak is particularly unique as it passes by highly productive areas (Coyle et al., 2012), is near current and planned future mariculture grounds, and has been suggested to be frequently exposed to widespread and sustained aragonite undersaturation as a direct result of ocean acidification (Bednarsek et al., submitted, Figure 3). In addition to monitoring ocean acidification in this ecologically and socio-economic important area, this additional transect will also help to better quantify the spatial variability along the coast and better constrain regional biogeochemical models (Hauri et al., 2020).

<u>Goals, Hypothesis, and Objectives</u>

The main goals of this proposed monitoring effort are to better identify ocean acidification hot spots in space and time through increased spatial and temporal sampling frequency, constrain the natural temporal and spatial variability of the inorganic carbon chemistry, estimate the ocean acidification rate, monitor the impacts of the progression of ocean acidification and climate change on the inorganic carbon system and ecosystem, and provide important data for the Gulf Watch and Mariculture Programs, the Gulf of Alaska Ecosystem Status Report and its broad readership, ecologists, and the ocean acidification community sampling networks. In addition, this data will fill an important data gap that is invaluable to the PI's ongoing biogeochemical modeling efforts that have already led to several collaborative publications (Hauri et al., 2020; Bednarsek et al., submitted; Hauri et al., accepted; Ohlberger et al., in prep.) and a publicly available online interactive modeling tool. These resources have spurred interest from NOAA, fisheries scientists, and ecologists alike.

Hypotheses:

Hypothesis 1: While ocean acidification is a gradual background process, natural spatial and temporal variability of inorganic carbon conditions can trigger ocean acidification extreme events in certain areas called "ocean acidification hot spots".

Hypothesis 2: These ocean acidification extreme events may lead to the early onset of conditions directly and indirectly harmful to key species, such as pink salmon (oil spill recovered species).

To ensure sustained long-term ocean acidification monitoring in the Spill Area, improve our understanding of the inorganic carbon system's natural variability, and define areas and species most vulnerable to the effects of ocean acidification I am proposing to:

Objective #1: Reinstitute and expand high-resolution ocean acidification monitoring in the Spill Area

Objective #2: Adjust open ocean sampling methodologies to sampling in estuarine and glaciated environments and over-constrain the inorganic carbon system to distinguish between carbonate and non-carbonate alkalinity

Objective #3 Post-process and archive the data within one year of water sample collection

Objective #4: Characterize the spatial and temporal variability of inorganic carbon parameters and identify their physical and biological drivers, and identify ocean acidification hotspots and marine resources most vulnerable to ocean acidification

Objective #5 Share information and knowledge with other Spill Area ocean acidification monitoring efforts, especially with the OA community sampling hubs, and PWSSC, and contribute to NOAA's annual Ecosystem Status Report (letter of support, Dr. Ferriss)

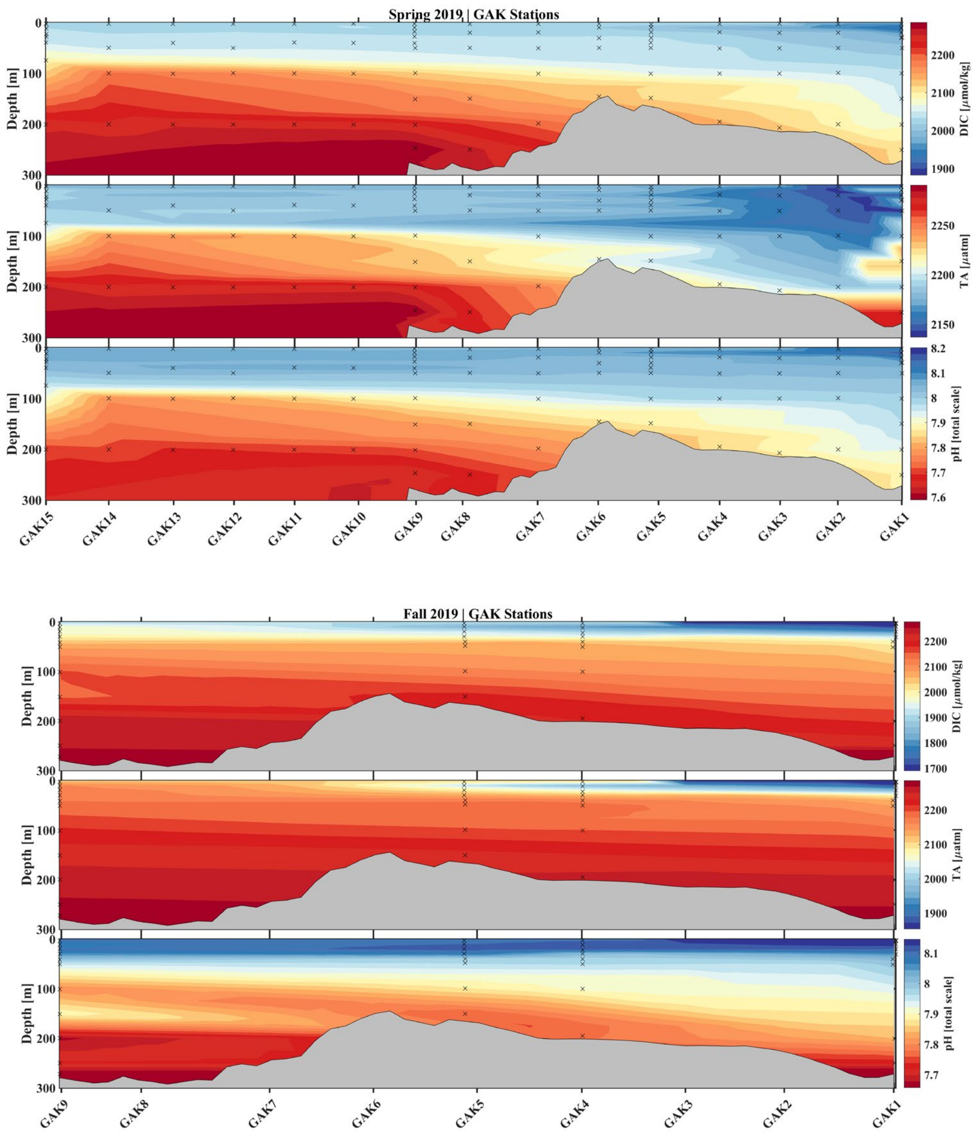

Figure 1. Seward Line transect showing contour plots of measured dissolved inorganic carbon (DIC), total alkalinity (TA), and pH during the NGA-LTER Spring (top) and Fall (bottom) cruises. Black crosses illustrate sampling stations. In spring 2019, all stations were sampled between GAK1 and GAK15 to better constrain the spatial variability (this was possible due to supplementary funding from NGA-LTER and volunteering by the Hauri laboratory. Only four stations between GAK 1 and GAK 9 were sampled in fall. This comparison shows that many spatial features get lost if the system is undersampled.

2. RELEVANCE TO THE INVITATION (maximum 300 words)

Discuss how the project addresses the projects of interest listed in the Invitation and the overall Program goals and objectives. Describe the results you expect to achieve during the project, the benefits of success as they relate to the topic under which the proposal was submitted, and the potential recipients of these benefits.

The proposed project aims at defining the rate of ocean acidification, constraining the natural variability of pH and other inorganic carbon variables, and identifying potential ocean acidification hotspots and refugia. It aligns well with the objectives, goals, and other projects of the Exxon Valdez Oil Spill Trustee Council (EVOSTC). This work will help to distinguish the effects of the oil spill from the effects of ocean acidification on the ecosystem and manage sensitive or injured species and resources. Regional surface pH has changed by about 0.08 only since 1980, which corresponds to roughly a 25% increase in acidity (Hauri et al., accepted). Given this large change, it is likely that some species have already been negatively affected by ocean acidification, potentially resulting in a slower recovery from the spill. For example, research suggests that elevated seawater CO_2 concentrations impair sensory systems of coho salmon (Williams et al., 2019). Furthermore, ocean acidification has already had a harmful effect on calcifying sea snails in the Gulf of Alaska (Bednarsek et al., submitted), an important food source for juvenile and adult pink salmon (Auburn and Ignell, 2000; Daly et al., 2019).

This project contributes to the "environmental drivers component" by monitoring pH, TA, and DIC and benefits the pelagic monitoring component by identifying potential ocean acidification hotspots that could be harmful to key species such as pink salmon. In addition, the project will produce important data for the NOAA Ecosystem Status Report (letter of support from Dr. Ferriss) to help inform fisheries managers on conditions and trends. The collected data will also be used by PI Hauri to better constrain her biogeochemical model (focus of other ongoing projects), which allows her to frame current and future monitoring work in a retrospective context that ties directly into the time period relevant for the spill.

3. PROJECT HISTORY (maximum 400 words)

Is this a new or continuing project? If continuing, please describe the history of the project and what has been accomplished to date (i.e., numbers of publications, presentations, podcasts etc.). Please include detailed references to products (i.e., publications, reports, and websites) in the literature cited section.

Although new to EVOSTC, the Seward Line has been sampled twice per year for inorganic carbon chemistry (TA and DIC) since 2008. During the first 10 years of the monitoring program, the Ocean Acidification Research Center at the University of Alaska Fairbanks conducted high-resolution ocean acidification monitoring along the Seward Line. Since 2018, only five stations have been sampled along this historic transect as a result of limited funding. PI Hauri took over the analysis of the water samples for TA, DIC, and pH, and post-processing, archiving, and publishing of the data in 2019 (Hauri et al., 2021) and is now looking for long-term financial support to ensure continued and expanded monitoring of the impacts of ocean acidification and climate change on the chemical environment of the Gulf of Alaska ecosystem. Since the beginning of this monitoring effort, the inorganic carbon data has been extensively used to describe the natural variability of the inorganic carbon system (Fabry et al., 2009; Evans et al., 2013 and 2014, 2015), provide an overview of the risks associated with ocean acidification to Alaska's fisheries sector (Mathis et al., 2014), and to evaluate regional biogeochemical ocean models (Siedlecki et al., 2017; Hauri et al., 2020 and Hauri et al., accepted). PI Hauri has made the output from a 34 year-long model simulation (1980 - 2013) from her regional biogeochemical ocean model publicly available. She also worked with Axiom Data Science (AOOS data manager) to ensure that the model output can be easily used to visualize oceanic conditions (100 variables) in the

Gulf of Alaska (https://gulf-of-alaska.portal.aoos.org/#module-metadata/e59675f8-795a-4769-bb27-06c322170e50). This model product has led to collaborations with ecologists, fisheries biologists, and economists (Bednarsek et al., submitted; Jan Ohlberger is working on a publication on impacts of ocean acidification on pink salmon, using our model output).

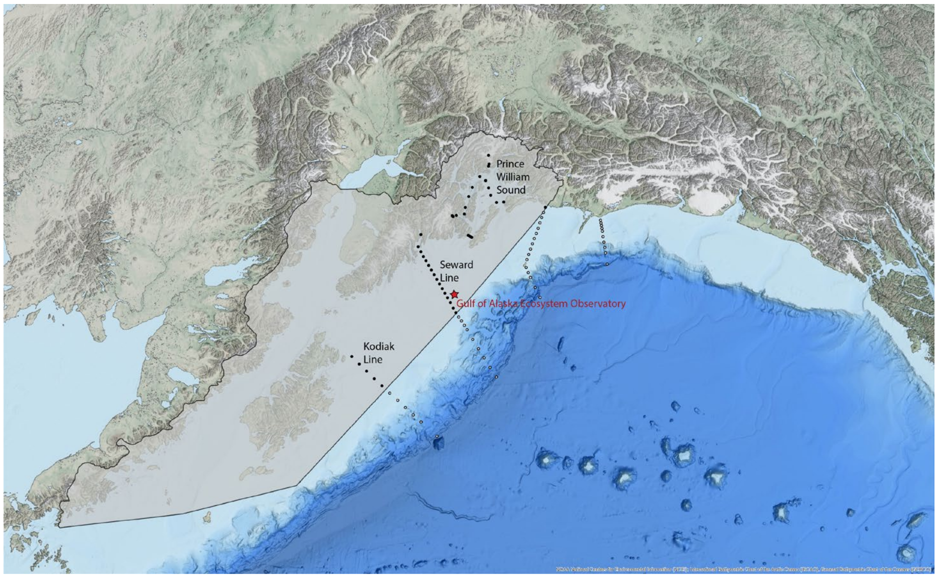

Figure 2. Map of the Northern Gulf of Alaska, illustrating the Exxon Valdez Oil Spill Area (shaded polygon), the Northern Gulf of Alaska Long Term Ecological Research (NGA-LTER) program sampling stations (dots), and the Gulf of Alaska Ecosystem Observatory (red star). Here we are proposing to monitor ocean acidification in at the stations located within the oil spill area, which are indicated with black filled dots.

PROJECT DESIGN

1. **Objectives and Hypotheses**

List the objectives of the proposed research and concisely state why the intended research is important. If your proposed project builds on recent work, provide justification that the data are valuable and will remain valuable and if any changes are proposed. If the proposed project is for new work, provide justification of how the project will provide data useful to addressing management objects, Program goals, and further the Council's mission of recovering injured natural resources and their services.

Clearly state the hypotheses, describe how these hypotheses contribute to natural resources and services in the Spill Area, and explain how the hypotheses support the monitoring efforts.

The Exxon Valdez Oil Spill was an acute and immediate catastrophe for the Gulf of Alaska ecosystem. This sudden threat occurred as an extreme stressor in the midst of multiple ongoing environmental stressors such as ocean acidification and climate change. These invisible environmental stressors may have played a role in silently slowing down the recovery of the natural resources and ecosystem services in the Spill Area and we seek to better understand and quantify the role of changing carbon chemistry. While there is a preponderance of evidence on how climate change is impacting the waters of the Gulf of Alaska through warming, freshening, and marine heat waves (Neal et al., 2010; Hood et al., 2015; Laufkoetter et al., 2020), no ocean acidification time-series in the Gulf of Alaska is currently long enough to distinguish between ocean acidification and natural variability, and determine a rate of change of pH and aragonite saturation state. Our first estimates of the rate of ocean acidification are solely based on a recent model study, which suggests highly variable rates of ocean acidification across the Gulf of Alaska (Hauri et al., accepted). The biogeochemical modeling study also suggests that 34 years of high-resolution data is still not long enough to distinguish between the high decadal-scale natural variability and the anthropogenic signal. Similarly, Henson et al., (2010) showed that about 40 years of high resolution data is necessary in order to distinguish between an anthropogenic trend and natural variability.

While such a long monitoring effort sounds daunting, monitoring efforts such as the one proposed here are important to gain a better understanding of the current state of the system and drivers and magnitude of the natural variability. These initial steps are necessary to eventually estimate the rate of ocean acidification (Hauri et al., 2018). While more and more nearshore time-series are established, oceanic focused sites are limited to the Seward Line transect and Prince William Sound, and the occasional NOAA cruise that occurs every 3 to 5 years. Given the high spatial and temporal variability of the physical, chemical, and biological environment in the Spill Area, and its vast geography, it is clear that the currently available observations are not sufficient to characterize and understand the heterogeneous spatial and temporal variability of inorganic carbon chemistry and the effects of ocean acidification in the Spill Area.

Here, we propose to leverage the NGA-LTER cruises and add pH, TA, and DIC measurements to the May, July, and September cruises for the next ten years to be able to document current conditions, estimate the rate of ocean acidification, define ocean acidification hotspots, and provide information for species response and recovery.

The main objectives of this monitoring component are:

Objective #1: Reinstitute and expand high-resolution ocean acidification monitoring in the Spill Area

Objective #2: Adjust open ocean sampling methodologies to sampling in estuarine and glaciated environments and over-constrain the inorganic carbon system to distinguish between carbonate and non-carbonate alkalinity

Objective #3 Post-process and archive the data within one year of water sample collection

Objective #4: Characterize the spatial and temporal variability of inorganic carbon parameters and identify their physical and biological drivers, and identify ocean acidification hotspots and marine resources most vulnerable to ocean acidification

Objective #5: Share information and knowledge with other Spill Area ocean acidification monitoring efforts, especially with the OA community sampling hubs, and PWSSC, and contribute to NOAA's annual Ecosystem Status Report (letter of support, Dr. Ferriss)

This proposed monitoring effort directly addresses one of the overarching goals of the EVOSTC to "monitor how factors other than oil may inhibit full recovery or adversely impact recovering resources". It also provides scientific data products on ocean acidification in the spill area to management agencies to help advance the Council's mission of recovering injured natural resources and their services.

Hypotheses:

Hypothesis 1: While ocean acidification is a gradual background process, natural spatial and temporal variability of inorganic carbon conditions can trigger ocean acidification extreme events in certain areas called "ocean acidification hot spots".

Hypothesis 2: These ocean acidification extreme events may lead to the early onset of conditions directly and indirectly harmful to key species, such as pink salmon (oil spill recovered species).

With these hypotheses in mind, our monitoring project will identify ocean acidification hotspots that will be paired with data on species distribution from other monitoring projects to better understand which species are potentially being impacted by ocean acidification (see objective #4 and Section 3). This combined information could then lead to new mitigation or adaptation strategies and studies on how these multiple stressors may affect communities.

2. **Procedural and Scientific Methods**

For each objective listed in A. above, identify the specific methods that will be used to meet the objective. Project proposals that seek to continue to contribute new data to the data sets collected in previous years using the same protocols and project design must provide justification that the past methods applied are still appropriate. If changes are needed based on current information a justification for the changes must be provided.

In describing the methods for collection and analysis, identify measurements to be made and the anticipated precision and accuracy of each measurement and describe the sampling equipment in a manner that permits an assessment of the anticipated raw-data quality.

If applicable, discuss alternative methods considered, and explain why the proposed methods were chosen. In addition, projects that will involve the lethal collection of birds or mammals must comply with the EVOSTC's policy on collections, available on our website.

Objective #1: Reinstitute and expand high-resolution ocean acidification monitoring in the Spill Area

We propose to collect a total of 250 discrete pH, TA, and DIC water samples at stations that are within the Spill Area during each of the NGA-LTER cruises in spring (April/May), summer (July), and fall (September) for the next ten years. The sampling will take place along the historic Seward Line and in Prince William Sound to re-establish high resolution monitoring at the stations that were regularly sampled between 2008 and 2017. In addition, we will take samples along the Kodiak Line, a transect that starts at the eastern-most tip of Kodiak Island. This will provide a better understanding of the spatial variability of inorganic carbon chemistry, produce meaningful data for the mariculture activities in this region, and start ocean acidification monitoring in a highly productive area (Coyle et al., 2012) that may possibly also be an ocean acidification hotspot (Bednarsek et al., submitted).

Objective #2: Adjust open ocean sampling methodologies to sampling in estuarine or glaciated environments and over-constrain the inorganic carbon system to distinguish between carbonate and non-carbonate alkalinity

Inorganic carbon sampling in glaciated coastal regions requires methodological variations from open-ocean best practices to ensure that suspended mineral particles do not bias DIC and TA measurements between sample collection and analysis, and that non-carbonate (organic) alkalinity does not introduce errors in the calculation of the remaining inorganic carbon parameters (Sejr et al., 2011; Byrne, 2014). Following these recommendations, we have revised the open-ocean sampling techniques to guarantee high quality data from this glaciated and estuarine environment. To avoid compromising our inorganic carbon seawater samples with $CaCO_3$ particles we will filter the DIC, pH, and TA samples straight from the Niskin bottles (Bockmon and Dickson, 2014) into pre-cleaned 500 mL borosilicate bottles (Dickson et al., 2007), and add mercuric chloride ($HgCl_2$) to the sample. DIC and pH will be analyzed simultaneously to avoid influence of air-sea gas exchange. All three variables will be analyzed from the same bottle.

pH will be determined spectrophotometrically with a CONTROS HydroFIA pH operating in discrete measurement mode (Aßmann et al., 2011) using purified m-Cresol Purple (mCP) as the indicator dye (Clayton and Byrne, 1993; Liu et al., 2011). At the beginning of each day, the HydroFIA pH will undergo a conditioning period using seawater with similar properties (e.g. an old CRM or sample) until values stabilize, generally less than 1 hour. Sample temperature will be stabilized at 25C+/-0.01 during measurements using Peltier elements and 4-5 repetitive measurements will be taken for each sample. Samples will be opened immediately (<5 minutes) before concurrent analyses of pH and DIC in an effort to limit gas exchange with ambient lab conditions. Certified Reference Material (CRM, known TA and DIC concentration) will be measured at the beginning and end of the day, as well as at least every 8 samples. In addition, Tris buffer in synthetic seawater standards will be measured approximately every other day and will be used to characterize instrument accuracy at higher pH values.

TA samples will be analyzed using a CONTROS HydroFIA TA (Seelmann et al., 2019; Seelmann et al., 2020b) operating in discrete measurement mode. TA will be determined by open-cell single-point titration with spectrophotometer pH determination using hydrochloric acid (HCl) as the strong acid and unpurified bromocresol green sodium salt (BCG) as the indicator solution (Seelmann et al., 2020a). Sample temperature will be constantly controlled to 25°C using a Peltier element heat exchanger. At the beginning of each day, the HydroFIA TA will undergo a conditioning period using seawater with similar properties (e.g. an old CRM or sample) until values stabilize, generally 8-10 measurement cycles. Next, a calibration routine will calibrate the analyzer using 5 repetitive measurements of a CRM of known alkalinity as recommended by Dickson et al. (2007). Samples will then be analyzed with 3-4 repetitive measurements. Samples will be analyzed for TA after being analyzed for pH and/or DIC, generally within 3 days of being opened.

Samples will be analyzed for DIC using an Apollo SciTech, LLC Dissolved Inorganic Carbon Analyzer model AS-C6. All species of dissolved inorganic carbon in a sample will be converted to CO_2 by the addition of a strong acid. The CO_2 gas is then purged from the sample through a drying system. The concentration of CO_2 gas will be measured using a non-dispersive infrared gas analyzer, the LI-7000 CO_2/H_2O Analyzer. This method will require a standard (e.g. CRM) to create a three-point calibration line. The calibration line will be used to quantify the total amount of CO_2 in the sample as the integrated area under the concentration-time curve. Apollo SciTech recommendations to improve analytical accuracy will be followed and will include bubbling CO_2 off the acid daily, allowing the analyzer to warm up for at least 1 hour before any measurements, conditioning the system with aged seawater (e.g. an old CRM or sample) for 0.5 to 1 hour to allow the analyzer to stabilize, measuring a set of standards at the beginning and end of each day and at least every 8 samples, filtering N_2 gas (although it is already UHP 99.999% Nitrogen) with a PTFE filter, CO_2 scrubber (Ascarite II) and H_2O scrubber ($Mg(ClO_4)_2$).

The analysis will be carried out as soon as possible after arrival at IARC/UAF. All efforts will be undertaken to minimize measurement uncertainty and attain the climate goal for DIC, TA, and pH uncertainties of 2 umol/kg, 2 umol/kg, and 0.003, respectively (Newton et al., 2015). Please refer to the next section on how we account for a total combined uncertainty during data post-processing.

<u>Objective #3: Post-process and archive the data within one year of water sample collection</u>

Post-processing of the data includes quality control, calculation of pH at in-situ conditions, CO_3^{2-}, CO_2, Ω_{arag} and other inorganic carbon system variables, instrument drift correction, and determination of uncertainty. The data will be manually quality assessed/controlled and flagged for obvious inconsistencies.

Following Orr et al. (2018), we will estimate uncertainties of derived carbonate variables. These uncertainties will be a total combined uncertainty and include random uncertainty (measurement precision) and systematic uncertainties (instrument accuracy, instrument drift calculated using repeat CRM measurements throughout each day, indicator dye impurities and perturbations, etc.).

We will continue working closely with Axiom Data Science to archive our data (Hauri et al., 2021) within one year of sampling. See Data Management Project below for details.

<u>Objective #4:</u> Characterize the spatial and temporal variability of inorganic carbon parameters and identify their physical and biological drivers, and identify ocean acidification hotspots and marine resources most vulnerable to ocean acidification

The details on the methodology to reach this Objective are outlined in the section “Data Analysis and Statistical Methods” below.

<u>Objective #5 Share information and knowledge with other Spill Area ocean acidification monitoring efforts, especially with the OA community sampling hubs, and PWSSC, and contribute to NOAA's annual Ecosystem Status Report (letter of support, Dr. Ferriss)</u>

Results from this project will fill gaps in other research efforts and provide important boundary information for near-shore ocean acidification studies. Currently, over 16 communities are involved in Tribally-led monitoring programs in the Gulf of Alaska, taking weekly water samples to document baseline carbon chemistry conditions in the near-shore environment. These time series are aimed to help understand the current water chemistry, seasonal changes, and potential natural influences in areas that are important for shellfish and other subsistence species. Data from the proposed project will augment findings from the near-shore sampling efforts with boundary conditions and help create a more complete picture of the conditions species are experiencing, particularly those that spend life history stages in both near-shore and offshore environments.

Direct transfer of knowledge will occur between Project PI Claudine Hauri and communities involved in sampling. Three Tribal hubs (Sitka Tribe of Alaska, Kodiak Area Native Association, and Chugach Regional Resources Commission) coordinate community samplers in each of their regions and have a robust program in place to communicate with communities on OA monitoring and education. These networks provides an existing platform to present results of the proposed project, hear from the community about ocean acidification information needs and concerns, and discuss directions of future research. Each hub holds an annual community water quality meeting/training with samplers and PI Hauri will join these meetings online or in person to participate in 2-way engagement.

As detailed below, we will also exchange knowledge and data with the PIs from EVOSTC project #21200127 (personal communication with Rob Campbell from PWSSC). PI Hauri has been approached by Dr. Ferriss from NOAA about potentially contributing ocean acidification monitoring data to NOAA's Ecosystem Status Report (ESR). Ocean acidification information was incorporated into an ESR for the first time last year for the Bering Sea with a positive response from the North Pacific Research Management Council, and similar data and forecasting results are sought after for the Gulf.

3. **Data Analysis and Statistical Methods**

Describe the process for analyzing data. Discuss the means by which the measurements to be taken could be compared with historical observations or with regions that are thought to have similar ecosystems. Describe the statistical power of the proposed sampling program for detecting a significant change in numbers based on statistical analyses such as power or sensitivity analysis. To the extent that the variation to be expected in the response variable(s) is known or can be approximated, proposals should demonstrate that the sample sizes and sampling times (for dynamic processes) are of sufficient power or robustness to adequately test the hypotheses. For environmental measurements, what is the measurement error associated with the devices and approaches to be used?

Analyses and methods proposed must be justified. Project proposals that seek to continue to contribute new data to the data sets collected in previous years using the same protocols and project design must provide justification that the past methods applied are still appropriate. If changes are needed based on current information a justification for the changes must be provided.

The data collected as part of this proposal will continue an ocean acidification time-series along the

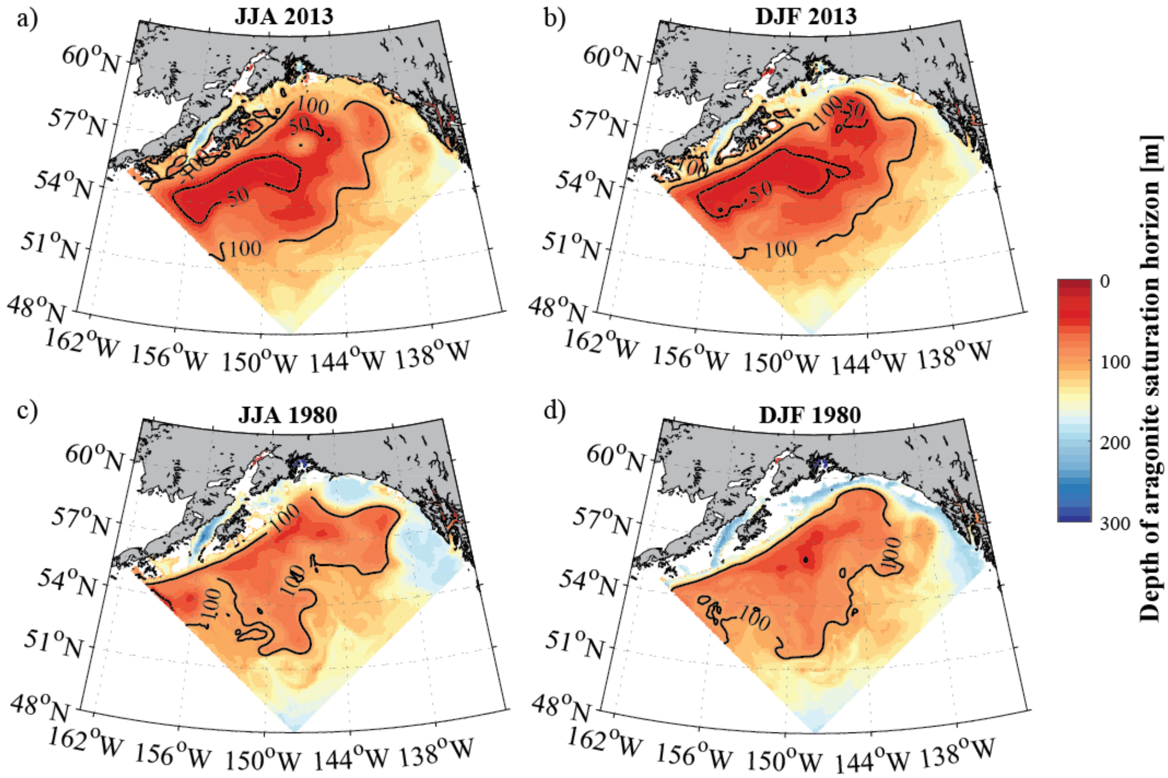

Figure 3. Average seasonal depth of the aragonite saturation horizon [m] in the Gulf of Alaska for June to August (left column) and December to February (right column) for 2013 (top row) and 1980 769 (bottom row). Solid black contour lines depict depth of the aragonite saturation horizon at 50 and 100 m. White areas show locations where the aragonite saturation horizon is deeper than the topography, indicating the absence of undersaturated waters on the shelf. Around Kodiak, the depth of the aragonite saturation horizon is especially shallow. Model output is from the GOA-COBALT hindcast simulation described in Hauri et al, (2020). This figure is taken from Bednarsek et al., submitted.

historic Seward Line and in Prince William Sound established in 2008. The proposed additional sampling in July will add important information about the influence of freshwater input on the inorganic carbon system and will provide data to better constrain the seasonal variability of the system. We acknowledge that with the proposed sampling schedule of May, July and September, we are missing important information about winter conditions. We will try to fill this gap with data from pH and pCO_2 sensors that PI Hauri has been operating as part of the Gulf of Alaska Ecosystem Observatory (Figure 2), which has been funded by a consortium including EVOSTC's Gulf Watch program, M.J. Murdock Charitable Trust, AOOS, NPRB's Long-term Monitoring program, and the University of Alaska Fairbanks (UAF).

The concentration of CO_3^{2-} and therefore Ω_{arag} ($\Omega_{arag} = (Ca^{2+})+(CO_3^{2-}) /K'_{sp}$, with estimations of K'_{sp} from *Mucci* (1983), will be calculated based on DIC, TA and pH. This will allow us to check for data inconsistencies and measurement errors (Byrne, 2014; Patsavas et al., 2015; Orr et al., 2018; van Heuven et al., 2011).

pH samples will be analyzed with purified mCP indicator dye (from Dr. Robert H. Byrne's laboratory, University of South Florida) to improve data quality (Liu et al., 2011). To ensure consistency with our historic dataset (Hauri et al., 2021; pH samples analyzed 2019-2021), we will follow the recommendation of Yao et al. (2007) and compare pH measurements of the same sample using purified and unpurified mCP. These measurements will be used to generate a batch-specific correction algorithm (Liu et al., 2011) and will be applied to the historic pH measurements obtained using unpurified mCP (Hauri et al., 2021). In addition, we will update data processing to incorporate dye perturbation corrections due to variable salinity data (Li et al., 2020).

Previously, pH values at in situ conditions were calculated with the CO2SYS Matlab routine (van Heuven et al., 2011) using input parameters pHlab and DIC, or pHlab and TA, or the average of the two when available (Hauri et al., 2021). For all calculations, the dissociation constants of Lueker et al. (2000), the HSO–4 dissociation constants of Dickson (1990), the fluoride dissociation constant of Dickson and Riley (1979), the borate dissociation constants of Dickson (1990), and the boron concentration of Lee et al. (2010) were used. These constants were selected due to their recommendation (Dickson et al., 2007) and widespread usage (e.g. Olsen et al., 2020; Jiang et al., 2021; Woosley, 2021). To our knowledge, no internal consistency study has been done within the EVOS area.

To fill this knowledge gap, we will investigate the internal consistency of the marine carbonate system to determine which constants are most suited to the large salinity and temperature ranges of the glacially influenced Gulf of Alaska (e.g. Woosley, 2021; Raimondi et al., 2019, Woosley et al., 2017, Chen et al., 2015). We will carefully evaluate our findings in light of recent work regarding pH-dependent discrepancies (e.g. Alvarez et al., 2021; Takeshita et al., 2020). Alvarez et al. (2021) suggested that inconsistencies between measured and calculated pH likely stem from variations in the spectrophotometric pH standard operation procedure. However, Takeshita et al. (2020) demonstrated that the discrepancy between spectrophotometrically measured pH using purified mCP and pH calculated from TA and DIC is more likely due to an incomplete understanding of the marine inorganic carbon model, rather than pH dependent errors in the spectrophotometric pH measurements.

We will also determine the importance of non-carbonate alkalinity, referred to as organic alkalinity or excess alkalinity (Fong and Dickson, 2019), in this system by examining the differences between calculated TA(DIC, pH) and measured TA (Byrne, 2014). This is important because estuarine sites often contain a significant amount of excess alkalinity, which is not accounted for in the computational models to derive other inorganic carbon parameters, such as carbon dioxide, carbonate ions, or Ω_{arag}, and could therefore introduce significant errors (e.g. Patsavas et al., 2015; Fong and Dickson, 2019; Sharp and Byrne, 2020).

The data collected through this project will be analyzed along with the historic data set. We will apply trend analysis to the historic and new data following Hauri et al., (accepted). Although it will likely take another 20 to 30 years of monitoring in order to be able to distinguish between an anthropogenic trend and natural variability (Henson et al., 2010; Hauri et al., accepted), the data will be of immediate value to characterize the spatial and temporal variability of inorganic carbon parameters, identify their physical and biological drivers throughout the water column and across the NGA-LTER study site, and locate ocean acidification hotspots. In order to do so, we will produce spatial maps of inorganic carbon variables, salinity, temperature, micro and macronutrients, primary production, phytoplankton abundance, and remineralization across seasons. This ancillary data is available momentarily to PI Hauri since she is also PI on the NSF funded NGA-LTER project. We will test for the influence of mixing, air-sea gas exchange of CO_2 and oxygen as well as primary production on the inorganic carbon system by including variables such as Chl-*a*, O_2, and nutrients in our regression analyses to see if they can explain any of the residual variability we see along saline to freshwater gradients (Hauri et al., 2020). Available wind and upwelling index data and algorithms will be used to explore the role of deep-water intrusion on bottom water inorganic carbon chemistry variability.

As a first step in identifying which living marine resources might be the most vulnerable to ocean acidification in the Spill Area and where additional monitoring resources would be valuable, we will compare the regional patterns of low aragonite saturation state/pH and high pCO_2 conditions to the spatial distribution of important and sensitive marine/fisheries resources from other monitoring efforts. We will follow the approach described in Mathis et al. (2014) to explore the intersection of ocean acidification hazard, the exposure of living marine resources to the ocean acidification hazard, and the vulnerability of the human system to changes caused by these factors.

The proposed data will also be invaluable to improve PI Hauri's regional oceanic biogeochemical model, which will then better portray how the biogeochemical environment in the Spill Area has already changed since the spill and how it may change in the future. While these modeling studies will be the focus of other projects, it is important to note here how important the proposed observations are to improve the biogeochemical model.

Description of Study Area

Is the study area within the Spill Area? Describe the study area, including maps and figures, if applicable, decimally-coded latitude and longitude readings of sampling locations or the bounding coordinates of the sampling region (e.g., 60.8233, -147.1029, 60.4739, -147.7309 for the north, east, south and west bounding coordinates).

The Seward Line has been sampled for salinity, temperature, nutrients, phytoplankton, and zooplankton in spring and late summer over the past 20+ years and has provided a good understanding of the physics and lower trophic ecosystem during these two seasons. This historic transect starts at the mouth of Resurrection Bay off Seward (59°50.7'N, 149°28.0'W) and continues south across the shelf to the shelf break (58°5.9'N, 147° W).

Here, we propose to collect DIC, TA, and pH water samples at the stations that are within the oil spill area (Figure 2, black dots) during the spring, summer, and fall cruises. This will allow for a continuation of the historic dataset along the Seward Line and in Prince William Sound, and expansion of long-term monitoring to the westernmost transect; the Kodiak Line (58°14.7’N, 151°35.4’W to 57°12.27’N, 149°43.17’W). The Kodiak Line was added to the NGA-LTER sampling lines in 2018 to better address the different features, processes, and scales seen within the NGA. This transect off Kodiak experiences the least influence from freshwater input, crosses shallow banks representing areas of high biological productivity (Coyle et al., 2012), and may cover an area with widespread and sustained aragonite undersaturation on the shelf (Bednarsek et al., submitted, Figure 3). Sustained monitoring in this vulnerable area is therefore important to improve our understanding of the current chemical conditions near Kodiak, create an ocean acidification baseline data set in this mariculture and fisheries important area, and fill a large data void in order to better evaluate our regional oceanic biogeochemical model, which will then allow us to simulate present day and future conditions with higher certainty (Hauri et al., 2020).

4. COORDINATION AND COLLABORATION

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

A preferred requirement for all proposals is to partner with the ASLC, PWSSC, or both Centers. If not collaborating with either of these Centers, please provide information as to the inquiries and efforts extended to ASLC and PWSSC researchers and/or administrators.

PI Hauri has been in touch with ASLC director Tara Riemer and Education and Outreach specialist Laurie Stuart regarding potential participation in the proposed Community Organized Restoration and Learning (CORaL) Network. The CORaL network is a collaborative proposal between the Alaska SeaLife Center, Prince William Sound Science Center, Alaska Sea Grant, Center for Alaska Coastal Studies, Chugach Regional Resources Commission, and the Alutiiq Museum and Archeological Repository to coordinate community science/outreach projects in the spill-impacted region. PI Hauri has talked with ASLC and PWSSC about incorporating data from the proposed transect samples, mooring, and model output from previous work into outreach products (which may include curricula, videos, and/or podcasts) about ocean acidification. If funded, this network is prone to provide new opportunities to our team, such as collaborations with communities, other scientists, and outreach specialists. Hauri and Dugan would also consider applying to the CORaL Network subgranting program to design, develop and install an ocean acidification exhibit at the Alaska SeaLife Center. The ocean acidification exhibit could incorporate real-time data from the Gulf of Alaska, imagery from field work, animations from ocean acidification models, large scale pteropods, and a touch tank with acidified water so visitors could see dissolving shells under the microscope firsthand.

B. Within the EVOSTC LTRM Program

Provide a list and clearly describe the functional and operational relationships with the other EVOSTC proposed projects in the LTRM Program. This includes any coordination that has taken or will take place and what form the coordination will take (project guidance, shared field sites or researchers, research platforms, sample collection, data management, equipment purchases, etc.).

Understanding the rate of change of ocean acidification, constraining the natural spatial and temporal variability of the inorganic carbon system, and identifying potential ocean acidification hotspots and refugia are important steps to distinguish the effects of the oil spill from the effects of ocean acidification on the ecosystem and manage sensitive or injured species and resources. While this project will provide the chemical measurements to better understand the short and long-term dynamics of the inorganic carbon system, we will work closely with other EVOSTC LTRM researchers to establish the biological link to better evaluate how ocean acidification may affect the pelagic and near-shore ecosystems.

Environmental Drivers Component

The proposed monitoring directly contributes to the "Environmental Drivers Component" by monitoring pH, TA, and DIC in the Spill Area. The samples will be taken in Prince William Sound, along the historic Seward Line, and along a transect starting at the most eastern tip of Kodiak Island (Northern Gulf of Alaska Long-term Ecological Research (NGA-LTER) program, PI R. Hopcroft, see letter of support). While the stations in Prince William Sound and along the Seward Line have been sampled for ocean acidification since 2008, the Kodiak Line is new, but important since it crosses areas with high biological productivity (Coyle et al., 2012) and potentially widespread and sustained aragonite undersaturation (Bednarsek et al., submitted, Figure 3). The sampling will take place during the NGA-LTER cruises (Hauri is Co-PI on the NSF funded NGA-LTER program), along with measurements of salinity, temperature, nutrients, phytoplankton, zooplankton, particles, Chl-a etc. These ancillary measurements have been funded through a consortium of different funding sources, including the National Science Foundation, Gulf Watch Alaska Program and the Alaska Ocean Observing System (AOOS). The proposed inorganic carbon measurements will therefore directly support these biological studies, and enable monitoring the biological responses towards changes in the chemical environment. Furthermore, the proposed monitoring effort will add spatial context to the pH and pCO_2 data collected at the Gulf of Alaska Ecosystem Observatory (Figure 2), which has been partially funded by the Gulf Watch Alaska program as well.

Pelagic Monitoring and Herring Research and Monitoring Components

Research suggests that ocean acidification impacts spill-affected species in various ways. For example, elevated CO_2 concentration impairs sensory systems of coho salmon (Williams et al., 2019) and is likely to affect pink salmon as well. Furthermore, ocean acidification has already had a harmful effect on calcifying sea snails (pteropods) in the Gulf of Alaska (Bednarsek et al., submitted), which is an important food source for juvenile and adult pink salmon (Auburn and Ignell, 2000; Daly et al., 2019). A growing literature on the effects of ocean acidification on herring draws an unclear picture with wide ranging results from CO_2 and high temperature induced physiological challenges for embryos to increased survival rate of the herring larvae under high CO_2 conditions (Villalobos et al., 2020; Sswat et al., 2018). While we have not yet established a direct personal connection to the "Pelagic and Herring" monitoring components, we would welcome future collaboration to help deepen this understanding.

Nearshore Monitoring Component

Although this project will not measure ocean acidification parameters in the intertidal and subtidal areas of the Gulf of Alaska, our effort may be of importance to the near-shore monitoring component (for example EVOSTC #21200127 "Gulf Watch Ocean Acidification Monitoring", PI Hetrick and EVOSTC #21120114-J "Long-term Monitoring of Oceanographic Conditions in Cook Inlet/Kachemak Bay, Alaska", PI Holderied) to discern the oceanographic influence on this environment. If funded, we will reach out to both PIs to find ways on how our effort can best contribute to their studies.

Synthesis and Modeling Component

The collected data will inform PI Hauri's regional oceanic biogeochemical model through model improvement and evaluation. Depending on future funding, PI Hauri is planning on running new hindcast simulations through present-day and forecasting simulations. These simulations will be of high relevance to fisheries and mariculture planning and management, as well as agencies such as NOAA to integrate the model output in the Gulf of Alaska ecosystem report. The data will also be publicly available and ready for use in any other synthesis or modeling components.

Data Management Project

Axiom is including services and budget for this project. The EVOSTC's data policy encourages full and open access to, and confident use of, the data and information used in and produced by programs and projects of the EVOSTC. These data need to be easily understandable, electronically accessible and well organized to allow policy makers, researchers, managers, and the general public to make well-informed decisions. As such, Axiom Data Science, through its partnership with the Alaska Ocean Observing System (AOOS) has considerable experience developing scientific data management infrastructure, and they provide experienced personnel to manage both data and metadata documentation according to federal quality control standards. This project will use the AOOS data management infrastructure (developed and maintained by Axiom Data Science) to manage and share the data generated through this effort, in accordance with the EVOSTC Data Management Procedures. This system uses the standards and best practices defined by the NOAA U.S. IOOS Data Management and Communications committee (IOOS, 2010). Among this infrastructure is an operational stack of open source software components developed by Axiom Data Science, with support from the NOAA Integrated Ocean Observing System (IOOS), EVOSTC, the National Science Foundation and more, which manages large numbers of continuous data feeds and a data catalog framework to integrate and disseminate a variety of data products. Data and data products generated by this project will be posted on the Research Workspace together with standards-compliant metadata for access by the EVOSTC. At the end of the project term, final QA/QC'd data and metadata will be made publicly available through the Gulf of Alaska data portal and made publicly accessible through the AOOS Gulf of Alaska data portal and distributed to DataONE for long-term preservation.

Data Types, Formats, and Metadata: This project will generate the following data: i) discrete water sample data at stations during the NGA-LTER cruises in spring (April/May), summer (July), and fall (September); ii) inorganic carbon sampling from water samples collected in glaciated areas; and iii) calculated concentrations of CO_3^{2-}, CO_2, Ω_{arag} and other inorganic carbon system variables.

Data will be stored in non-proprietary formats to ensure re-use and long-term preservation. Project data may initially exist in proprietary or binary formats as primary-level data, depending on the source provider. Though the data may be in a state which can be easily utilized by the research team, in many cases the primary-level data is not in a form ready to be shared with the broader science community or integrated with other datasets. All provisional data will be manually quality assessed/controlled and flagged for obvious inconsistencies during the post-processing phases of the project. The final format for project data will be in open standard suitable for long-term archiving, such as:

- Containers: TAR, GZIP, ZIP
- Databases: CSV, XML
- Tabular data: CSV
- Geospatial vector data: SHP, GeoJSON, KML, DBF, NetCDF
- Geospatial raster data: GeoTIFF/TIFF, NetCDF, HDF-EOS
- Moving images: MOV, MPEG, AVI, MXF
- Sounds: WAVE, AIFF, MP3, MXF
- Statistics: ASCII, DTA, POR, SAS, SAV
- Still images: TIFF, JPEG 2000, PDF, PNG, GIF, BMP
- Text: XML, PDF/A, HTML, ASCII, UTF-8
- Web archive: WARC.

Comprehensive metadata using the latest national and international technology and community standards will be written for each data collection generated. The Research Workspace includes an integrated metadata editor, allowing researchers to generate metadata conforming to the FGDC-endorsed ISO 19110 and 19115-2 suite of standards. Axiom will provide technical assistance to project researchers to ensure robust and standards-compliant metadata are generated for final project datasets prior to data publication and archive.

Data Access and Timeframes: Among the Axiom data system infrastructure is the Research Workspace, a web-based scientific collaboration and data management tool used by researchers to secure and centralize project data, generate standards-compliant metadata, and ultimately elect data files and derived data products to be published openly on public data portals and in long-term data archives. Following the EVOSTC data sharing policies, all monitoring data from this project will be transferred as they become available to the Research Workspace. These data shall be replaced in the Research Workspace with QA/QC'd and metadata when available and no later than 1 year after collection, after which they will be made publicly available through the GOA data portal. The Research Workspace is the gateway for PIs to elect and publish data and metadata to the GOA data portal. The exception is for process studies which are research-oriented in nature and do not have annual timeseries data. Process studies require data and metadata to be made publicly available through the GOA data portal by the end of the project term

Data Storage, Preservation, and Archiving: The Axiom data center and services are housed on highly redundant storage and compute resources at a data center in Portland, OR, and are geo-replicated using Amazon Glacier Cloud Archive Services. All databases and code repositories are routinely backed-up, and servers undergo routine maintenance to swiftly address security vulnerabilities. Servers containing source code and databases are located behind an enterprise-level firewall and are physically secure with environmental regulation systems, redundant power, and fire suppression. Axiom's HPC resources are composed of approximately 2500 processing cores staged in a series of interconnected blade arrays as well as 1.8 petabytes of storage. Dedicated disc-space in the amount of 30 TBs will be allocated for long-term storage of all preliminary and finalized data resources produced by this effort.

For long-term preservation, all final data and metadata will be transferred to a national data center. The data developed in this project will be open source and licensed in the public domain. The planned archive for the data collected by this effort is the Research Workspace's DataONE Member Node. The Research Workspace hosts an integrated system for automating dataset submission to the NSF-sponsored DataONE federation of data repository. The Research Workplace supports and issues Digital Object Identifiers (DOIs), so datasets can be confidentially referenced in the published literature. Upon final permission from the project PI at the end of the project term, final data or data products will be submitted for archive with technical support by Axiom data management staff to ensure appropriate use and compliance with the data center archive requirements.

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

Indicate how your proposed project relates to, complements, or includes collaborative efforts with the existing projects funded by the EVOSTC that are not part of an EVOSTC-funded program. Anticipated continuing individual projects for FY22 include project numbers 21210128, 21200127, and 21110853. Use the project search function for project details.

Project #21200127 focuses on adding ocean acidification (OA) data from Prince William Sound and Kachemak Bay to the existing GulfWatch Program oceanographic monitoring datasets. In discussing our project and project #21200127 with PI Rob Campbell from Prince William Science Center it has become clear that our projects nicely complement each other in time and space. We have also agreed on exchanging data and findings between the two projects, which PI Hauri may additionally use to improve her regional oceanic biogeochemical model.

Project #21110853 PI Kuletz is also Co-PI on the NGA-LTER, which opens up an easy communication channel between these two projects. A potential collaboration idea could be to explore whether seabirds are indirectly impacted by ocean acidification through food web changes.

C. **With Proposed EVOSTC Mariculture Focus Area Projects**

Indicate how your proposed project relates to, complements, or includes collaborative efforts with proposed EVOSTC mariculture focus area projects.

Our proposed sampling stations are located nearby current and planned mariculture grounds. While cultivation of shellfish may likely be negatively affected by ocean acidification (Barton et al., 2012), planted kelp or seaweed may positively change the in situ chemical environment and create ocean acidification refugia for organisms sensitive to high pCO_2/low pH. It is crucial to monitor the inorganic carbon system along with the mariculture development to understand these nuances. PI Hauri has reached out to Ginny Eckert and Jordan Hollarsmith to explore opportunities for collaboration, but has not heard back yet. While inorganic carbon monitoring in mariculture areas would require in situ moored pH and pCO_2 sensors with high resolution measuring capabilities, the proposed sampling along the Kodiak and Seward Lines, and in Prince William Sound would give an oceanic context to the more local conditions on the mariculture grounds. PI Hauri would also be interested in playing an advisory role in case the mariculture teams are planning an ocean acidification component.

The proposed sampling activities are essential to better constrain regional biogeochemical models, which could then be used to inform strategic mariculture planning and management.

D. With Proposed EVOSTC Education and Outreach Focus Area Projects

Indicate how your proposed project relates to, complements, or includes collaborative efforts with proposed EVOSTC education and outreach focus area projects.

As mentioned above, we are planning on collaborating with the proposed CORaL network. Furthermore, PI Hauri is also a Co-PI on a proposal called "Inspiring Seascapes: Growing the next generation of environmental scientists through experiential learning in Kenai Fjords and Kachemak Bay", which is being submitted in response to the EVOSTC Education and Outreach Focus Area Project RFP. This proposed education and outreach project would organize two tuition-free multi-day expeditions called "*Girls in Icy Fjords" and "Girls on Water"* for high school girls in Kachemak Bay and Kenai Fjords to explore the physical, biological, and social components of coastal, Spill-affected Alaska by sea kayak. These expeditions would be based on the successful *Inspiring Girls Expeditions* (inspiringgirls.org), which has fostered the next generation of environmental scientists by providing opportunities for 16 and 17 year-old youth to connect with remote landscapes and natural sciences for over 20 years. The expedition curriculum would include inquiry-based learning, contributions to active EVOSTC research and monitoring, and discussions with leading scientists, managers, tourism personnel, Elders and other community members living and working in Spill-affected areas. Dr. Hauri was the founder of *Girls in Icy Fjords* and has already developed mechanisms for incorporating her research into the curriculum for participants, including hands-on experiments with seawater and glacier ice, to show how melting glaciers affect seawater pH. She will work on additional curriculum to incorporate ocean acidification research into the daily activities of the participants.

E. With Trustee or Management Agencies

Please discuss if there are any areas which may support EVOSTC trust or other agency work or which have received EVOSTC trust or other agency feedback or direction, including the contact name of the agency staff. Please include specific information as to how the subject area may assist EVOSTC trust or other agency work.

If the proposed project requires or includes collaboration with other agencies, organizations, or scientists to accomplish the work, such arrangements should be fully explained, and the names of agency or organization representatives involved in the project should be provided. If your proposal is in conflict with another project or program, note this and explain why.

PI Hauri is in contact with Bridget Ferris, a research biologist at NOAA's Alaska Fisheries Science Center and lead editor of the Gulf of Alaska Ecosystem Status Report, who has expressed her excitement about this proposed project as it would complement NOAA's ocean acidification projects and contribute to their annual Ecosystem Status Reports and ecosystem-based fisheries management (letter of support).

All in all, we look forward to initiating conversations with other agencies to ensure the best use of this data.

F. With Native and Local Communities

Provide a detailed plan for local and Alaska Native community involvement in the project. ***This is a mandatory requirement for all proposals.***

We will collaborate with the tribal organized ocean acidification community sampling networks in Southeast, Southcentral, and Kodiak which are currently involved in weekly sampling for ocean acidification. Three Tribal entities (Sitka Tribe, Chugach Regional Resources Commission, and the Kodiak Area Native Association) coordinate weekly sampling in over 20 communities statewide to develop baseline data on ocean acidification to better understand the risk of ocean acidification to subsistence resources. These entities have expressed interest in and are in support of additional information that can be gathered to help understand conditions and drivers and strengthen ocean acidification forecasting in the region (personal communication with this team). Collaboration will involve two-way sharing of results and participation during annual meetings to additionally exchange knowledge. Darcy Dugan, who is the director of the Alaska Ocean Acidification Network and unfunded collaborator on this project, will facilitate this knowledge exchange and will introduce PI Hauri to the members of the community sampling networks.

We will also work closely with the GulfWatch Alaska program to support their activities in Alaska Native communities (personal communication with Many Lindeberg, program lead GulfWatch Alaska).

Additionally, the Alaska Ocean Acidification Network works to connect researchers with audiences in communities throughout the state through conferences, science nights and other events. Dugan will look for opportunities for results to be shared through these avenues and in coordination with the proposed CoRAL Network. An emphasis during these presentations will be 2-way information exchange.

5. DELIVERABLES

List and describe expected products that will come from this project. Deliverables include but are not limited to papers, reports, recordings, films, websites, presentations, data, and metadata. Project PI(s) will be responsible for all deliverables unless otherwise noted below.

- Archived data product with DOI: PI Hauri has been working closely with Axiom Data Science (AOOS manager) on properly archiving the Seward Line inorganic carbon data (Hauri et al., 2021). As part of this project we will continue this effort and will make the data available within one year of collection.

- Reports following the EVOSTC reporting guidelines.

- Findings from the data published in a peer-reviewed journal (e.g. updated risk assessment). The data will also be used for regional oceanic biogeochemical model evaluation purposes and will be published.
- Annual story on the project and disseminate results through the Alaska Ocean Acidification Network.
- Presentations during community sampling network annual water quality meetings/trainings in Sitka, Seward and Kodiak.
- Contribution to the Gulf of Alaska Ecosystem Status Report

6. PROJECT STATUS OF SCHEDULED ACCOMPLISHMENTS

Milestones are annual steps to meet overall objectives.

Tasks are annual steps to meet milestones (for example, sample collection, data analysis, manuscript submittal, etc.)

Deliverables are products that will be produced from the project (see section 6 above).

For each milestone, task, and deliverable listed, specify by each quarter of each year these will be accomplished. C = completed, X = planned or not completed.

For multi-year projects, reviewers will use this information in conjunction with project reports to assess whether the project is meeting its objectives and is suitable for continued funding.

Project milestone and task progress by fiscal year and quarter, beginning February 1, 2022. C = completed, X = planned or not completed. Fiscal Year Quarters: 1= Feb. 1-April 30; 2= May 1-July 31; 3= Aug. 1-Oct. 31; 4= Nov. 1-Jan 31. *Annual review and reporting policy will be discussed at the January 2020 Council meeting. Any changes will be posted on the website.

	FY22				FY23				FY24				FY25				FY26			
Milestone/Task	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Spring inorganic carbon sampling																				
Cruise preparation	X				X				X				X				X			
Sampling		C				C				C				C				X		
Laboratory analysis		X		C		X		C		X		C		X		C		X		C
Summer inorganic carbon sampling																				
Cruise preparation		X				X				X				X				X		
Sampling		C				C				C				C				C		
Laboratory analysis			X	C			X	C			X	C			X	C			X	C
Fall inorganic carbon sampling																				
Cruise preparation			X				X				X				X				X	
Sampling			C				C				C				C				C	
Laboratory analysis				X	C			X	C			X	C			X	C			X
Data Analysis																				
Purified vs unpurified mCP study		X			C															
Substandard calibration study			X			C														

Internal consistency study			X			C														
Data post-processing						C			C				C				C			
Data Archival																				
Data archival in collaboration with Axiom						C				C				X				C		
Reporting																				
*Annual reports					X				X				X				X			
FY work plan				X				X				X				X				X
Deliverables																				
Archived data product with DOI						C				C				C				C		
Contribution to Gulf of Alaska Ecosystem Status Report				X				X				X				X				X
Community sampling network annual water quality meetings				X				X				X				X				X
Annual story on the project through Alaska Ocean Acidification Network					X				X				X				X			
Findings published in peer reviewed journal																				C

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
Spring inorganic carbon sampling																				
Cruise preparation	X				X				X				X				X			
Sampling		C				C				C				C				C		
Laboratory analysis		X		C		X		C		X		C		X		C		X		C
Summer inorganic carbon sampling																				
Cruise preparation		X				X				X				X				X		
Sampling		C				C				C				C				C		
Laboratory analysis			X	C			X	C			X	C			X	C			X	C
Fall inorganic carbon sampling																				
Cruise preparation			X				X				X				X				X	
Sampling			C				C				C				C				C	
Laboratory analysis				X	C			X	C			X	C			X	C			X
Data Archival																				
Data analysis	X				X				X				X				X			
Data post-processing	C				C				C				C				C			
Data archival in collaboration with Axiom		C				C				C				C				C		
Reporting																				
*Annual reports	X				X				X				X				X			
FY work plan				X				X				X				X				
Final report																				X
Deliverables																				
Archived data product with DOI		C				C				C				C				C		
Contribution to Gulf of Alaska Ecosystem Status Report				X				X				X				X				X

Community sampling network annual water quality meetings				X				X				X				X				X
Annual story on the project through Alaska Ocean Acidification Network	X				X				X				X				X			
Findings published in peer reviewed journal																				C

7. Budget

A. Budget Forms (Attach)

Please provide completed budget forms (Excel workbook). Please note that costs associated with international travel for meetings, symposia, or presentations will not be considered for funding. Costs associated with outreach or education should be included in the Program budget. Include a screen shot of the "Summary" worksheet (example below).

Budget Category:		Proposed FY 22	Proposed FY 23	Proposed FY 24	Proposed FY 25	Proposed FY 26	5- YR TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel		$71,359	$70,768	$57,935	$59,384	$60,868	$320,314	
Travel		$0	$331	$0	$365	$0	$696	
Contractual		$0	$0	$0	$0	$0	$0	
Commodities		$43,875	$30,750	$30,750	$30,750	$30,750	$166,875	
Direct Costs Exempt from F&A		$0	$0	$0	$0	$0	$0	
Equipment		$0	$0	$0	$0	$0	$0	
Indirect Costs (non-equipment)	Rate = 25%	$28,809	$25,462	$22,171	$22,625	$22,905	$121,971	
SUBTOTAL		$144,043	$127,311	$110,856	$113,124	$114,523	$609,856	
General Administration (9% of subtotal)		$12,964	$11,458	$9,977	$10,181	$10,307	$54,887	N/A
PROJECT TOTAL		$157,100	$138,800	$120,900	$123,400	$124,900	$665,100	
Other Resources (In-Kind Funds)		$0	$0	$0	$0	$0	$0	

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		$62,390	$63,950	$65,548	$67,187	$68,867	$327,942		$648,256
Travel		$402	$0	$443	$0	$489	$1,334		$2,030
Contractual		$0	$0	$0	$0	$0	$0		$0
Commodities		$30,750	$30,750	$30,750	$30,750	$30,750	$153,750		$320,625
Direct Costs Exempt from F&A		$0	$0	$0	$0	$0	$0		$0
Equipment		$0	$0	$0	$0	$0	$0		$0
Indirect Costs (non-equipment)	Rate = 25%	$23,386	$23,675	$24,185	$24,484	$25,027	$120,757		$242,728
SUBTOTAL		$116,928	$118,375	$120,926	$122,421	$125,133	$603,783		$1,213,639
General Administration (9% of subtotal)		$10,523	$10,654	$10,883	$11,018	$11,262	$54,340	N/A	$109,227
PROJECT TOTAL		$127,500	$129,100	$131,900	$133,500	$136,400	$658,400		**$1,323,500**
Other Resources (In-Kind Funds)		$0	$0	$0	$0	$0	$0		**$0**

B. Sources of Additional Funding

Fill out the summary table below (should match the table on page 2). Provide a narrative that Identifies non-EVOSTC funds or in-kind contributions used as cost-share for the work in this proposal. List the amount of funds, the source of funds, and the purpose for which the funds will be used. Do not include funds that are not directly and specifically related to the work being proposed in this proposal. Please attach documentation from additional project funding sources which confirms and describes matching funds, including date(s) the matching funds are/will be authorized.

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

FY22	FY23	FY24	FY25	FY26	FY22-26 Total
					*See paragraph below
FY27	**FY28**	**FY29**	**FY30**	**FY31**	**FY27-31 Total**
					*See paragraph below
				FY22-31 Total	**See paragraph below*

This effort will leverage off the funded NGA-LTER project through use of ship-time, sampling personnel, and shipment of samples and gear between Fairbanks and Seward (letter of support by Dr. Hopcroft), funded through NSF, EVOSTCs GulfWatch Alaska program, AOOS, NPRB). Samples will be analyzed in the Hauri laboratory, an established lab outfitted with an Apollo DIC Analyzer AS-C5, and CONTROS HydroFIA pH and HydroFIA TA analyzers (funded through the International Arctic Research Center, and NSF). The project will also use data from the funded Gulf of Alaska Ecosystem Observatory to add temporal context to the data collected by this project (funded through The M.J. Murdock Charitable Trust, AOOS, NPRB, EVOSTCs Gulf Watch Alaska, and UAF). [UAF will not provide matching support for this project, only leveraged assets. Leveraged assets are not quantified.]

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Provide literature cited in the proposal.

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8. PROJECT PERSONNEL

*The CV's of all Principal Investigators and other senior personnel involved in the proposal must be provided. Each resume is limited to **two** consecutively numbered pages and must include the following information:*

- *A list of professional and academic credentials, mailing address, and other contact information (including e-mail address)*
- *A list of up to 10 of your most recent publications most closely related to the proposed project and up to five other significant publications. Do not include additional lists of publications, lectures, etc.*
- *A list of all persons (including their organizational affiliations) in alphabetical order with whom you have collaborated on a project or publication within the last four years. If there have been no collaborators, this should be indicated.*

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Professional Credentials:

University of Basel, Switzerland	Biology	B.S. 2005
University of Basel, Switzerland & Australian Institute for Marine Science	Animal Sciences	M.S. 2007
ETH, Switzerland	Environmental Sciences	Ph.D. 2012

Academic Credentials:
2015 – Pres. Research Assistant Professor, IARC-UAF
2014 – 2017 Postdoctoral Fellow, IPRC-UH
2012 – 2014 Postdoctoral Fellow, IMS-UAF
2012 Postdoctoral Fellow, ETH Switzerland

Products Most Closely Related to the Proposed Research:

Hauri, C., Schultz, C., Hedstrom, K., Danielson, S**.,** Irving, B.**,** Doney, S.C., Dussin, R., Curchitser, E.N., Hill, D.F, and Stock, C.A.: A regional hindcast acidification in the Gulf of Alaska, *Biogeosciences*, 17, 3837-3857, doi:10.5194/bg-17-3837-2020, 2020.

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Gruber, N., **Hauri, C.**, Lachkar, Z., Loher, D., Froelicher, T. L., and Plattner, G.- K.: Rapid progression of ocean acidification in the California Current System, *Science*, 337, 220- 223, doi:10.1126/science.1216773, 2012.

Collaborators:

Aguilar-Islas, Ana (UAF), Aritoli, Yuri (PML), Assmann, Steffen (Kongsberg), Barbero, Leticia (NOAA), Beaudreau, Anne (UAF), Bednarsek, Nina (Southern California Coastal Water Research Project), Berman, Matt (UAA),Bhatt, Uma (UAF), Bidlack, Allison (UAS), Bienek, Peter (UAF), Black, Jessica (UAF), Carothers, Courtney (UAF), Carter, Brendan (NOAA), Clucas, Tania (UAF), Conner, Laura (UAF), Cooper, Lee (University of Maryland), Creed, Elizabeth (Kongsberg), Curchitser,Enrique (Rutgers University), Danielson, Seth (UAF), Dussin, Raphael (GFDL), Evans, Wiley (Hakkai Institute), Fassbender, Andrea (NOAA), Feely, Richard (NOAA-PMEL), Fellman, Jason (UAS), Fiechter, Jerome (UCSC), Frei, Susan (UAF), Fujii, M (Hokkaido University), Gaitan Espitia, Juan Diego (University of Hong Kong), Grebmeier, Jackueline (University of Maryland), Hayes, Daniel (Advanced Offshore Operations Inc.), Hedstrom, Katherine (UAF), Hermann, Albert J. (NOAA), Hill, David (OSU), Hollingsworth, Teresa (USFS Boreal Ecology Coop Reasearch Unit), Hood, Eran (UAS), Hopcroft, Russel (UAF), Horne, John (NOAA), Hurst, Tom (Alaska Fisheries Science Center), Iken, Katrin (UAF), Irving, Brita (UAF), Isensee, Kirsten (IOC UNESCO), Jandt, Randi (UAF), Johnson, Mark (UAF), Kelley, Amanda (UAF), Kimoto, Katsunori (JAMSTEC), Klein, Eric (UAA), Konar, Brenda (UAF), Krumhardt, Kristen (University of Colorado), Lalande, Catherine (University of Laval), Larson, Angela (Goldstream Group), Lauvset, Siv (NORCE), Lennert, Kunuk (*Greenland* Institute of Natural Resources*)*, Leonard, Beth (UAA), Levin, Phillip (University of Washington), Little, Joseph (UAF), Lovenduski, Nikki (University of Colorado), Mahoney, Andy (UAF), McCammon, Molly (AOOS), McDonnell, Andrew (UAF), McPhee, Megan (UAF), Melkers, Julia (Georgia

Institute of Technology), Mitchell, Brian (Scripps), Moran, Thomas (UAF), Mueter, Franz (UAF), Munk, LeeAnn (University of Alaska Anchorage), Naish, Kerry-Ann (UW), Negrete-Garcia, Gabriella (SCRIPS), Neto, Francelina, (California State Polytechnic University, Pomona), NEWTON, JAN (UW), Niemi, Andrea (Fisheries and Oceans Canada Freshwater Institute), O'Donnell, Michael (California Ocean Science Trust), Ohlberger, Jan (UW), Pettit, Erin (OSU), Pilchner, Darren (NOAA), Pinchuk, Alexei (UAF), Prakash, Anupma (UAF), Riordan, John (Cindy Zook Associates), Rivlin, Tanya (Hebrew University of Jerusalem), Roberts, Dar (Univeristy of California Santa Barbara), Schmidt, Jennifer (UAA), Schneider, Kenneth (Stanford), Schultz, Cristina (Princeton University), Schwoerer, Tobias (UAF), Seitz, Andrew (UAF), Signorini, Sergio (NASA), Stafford, Kate (UW), Stammerjohn, Sharon, (University of Colorado), Statscewich, Hank (UAF), Steinberg, Deborah (VIMS), Stock, Charles (GFDL), Strom, Suzanne (Western Washington University), Stuecker, Malte (University of Hawaii), Stuefer, Martin (UAF), Sutton, Adrienne (NOAA), Sutton, Trent (UAF), Thibodeau, Patricia (VIMS), Triest, Jack (4h-Jena), Truffer, Martin (UAF), Veazey, Alice (UAF), Weingartner, Thomas (UAF), Wells, Mark (Umaine), Westley, Peter (UAF), Widdicoombe, Stephen (PML), Williams, Nancy (USF), Winsor, Peter (WWF), Wooller, Mathew (UAF)

9. SUGGESTED REVIEWERS (for new project proposals only)

Please identify person(s) not associated with individuals or institutions submitting this proposal, but with sufficient expertise and credentials to review the proposal in an unbiased and objective manner. Full contact information is required for a minimum of 5 people. These individuals may be asked to conduct a peer review of your proposal. It is suggested that you contact your proposed reviewers to confirm that they are willing to provide a review. Peer review may also be conducted by others not identified here.

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Alaska Ocean Observing System
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Alaska Ocean Acidification Network

March 25, 2021

Dear EVOS Trustee Council,

I would like to state my full support for the proposal "Continuation and expansion of ocean acidification monitoring in the Exxon Valdez Oil Spill area" submitted by Claudine Hauri at the University of Alaska Fairbanks. The proposed project will respond to the established need to increase time-series carbon chemistry data in the Gulf of Alaska to better understand ocean acidification conditions and potential impacts.

AOOS represents a network of critical ocean and coastal observations, data and information products that aid our understanding of the status of Alaska's marine ecosystem and allow stakeholders to make better decisions about their use of the marine environment. The mission of AOOS is to address regional and national needs for ocean information, gather specific data on key coastal and ocean variables, and ensure timely and sustained dissemination and availability of these data. AOOS also coordinates the Alaska Ocean Acidification Network which was established in 2016 to engage with scientists and stakeholders to expand knowledge on OA processes, consequences, and adaptation strategies. Our members range from academic and agency scientists to fishermen, shellfish growers, Tribes, educators, and coastal residents. Since Alaska is expected to experience ocean acidification faster and more intensely than other parts of the globe there is a critical need for research and public outreach to aid in future adaptation.

AOOS and the Alaska Ocean Acidification Network are keenly interested in this proposal as it fills an identified gap: long term, spatial, high resolution carbon chemistry data in the Gulf of Alaska. AOOS was part of a consortium that helped fund bi-annual carbon chemistry sampling along the Seward Line from 2008 to 2017 but this effort was sharply scaled back in 2018 due to funding limitations. While AOOS cannot currently cover the shortfall, we have committed to working with the research community to secure funding to make sure this work takes place. The proposed project would not only resume that time series but also expand data collection to the Gulf of Alaska LTER transects and add an additional month of sample collection (July). This additional data will help identify ocean acidification hot spots, provide information needed to estimate the ocean acidification rate, improve our understanding of variability and drivers, and provide important data and information for other programs including GulfWatch Alaska, mariculture initiatives, the Gulf of Alaska Ecosystem Status Report, and OA community sampling networks which have sprung up in Southeast, Southcentral and Kodiak.

As the director of the Alaska Ocean Acidification Network, I am happy to lead outreach for this project and will do my best to make sure the data and products are shared with researchers, resources managers and community members. I will connect PI Claudine Hauri directly with community sampling networks in the Gulf for 2-way exchange of information, and will highlight project findings through the Alaska OA Network website, eNews, and other communication avenues.

Sincerely,

Darcy Dugan
Alaska Ocean Acidification Network Director
Alaska Ocean Observing System

NGA LTER

COLLEGE OF FISHERIES AND OCEAN SCIENCES
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March 19, 2021

Re: Continuation and expansion of Ocean Acidification monitoring in the Exxon Valdez Oil Spill area

As the Principal Investigator of the Northern Gulf of Alaska Long Term Ecological Research (NGA-LTER) program, I acknowledge that the program will cooperate in supporting the activities of the proposal entitled "Continuation and expansion of ocean acidification monitoring in the Exxon Valdez Oil Spill area" with Claudine Hauri as the Principal Investigator.

We welcome the continued participation of Hauri's team to collect discrete inorganic carbon water samples during our Northern Gulf of Alaska Long Term Ecological Research cruises in 2022 through 2031. Hauri has been collecting such samples at a small subset of 5 stations since 2018, but with this number of stations we are finding interpretation of data extremely challenging. A more extensive sampling program is required to make this data usably robust. As evident from her budget the costs to accomplish this could not simply be accommodated within the LTRM GWA proposal for the Seward Line.

The CTD operations she requires are already part of our core activities, and there is adequate water capacity of Niskin bottles to meet her sample needs. The samples will be collected by an already designated on-board technician, so no additional berth will be necessary. Hauri is already involved in the NGA-LTER program, thus she will have immediate access to the concurrent physical and biological data collected during the cruises.

The Seward Line/NGA-LTER builds on nearly 25 years of observational oceanography on the Northern Gulf of Alaska Shelf. Part of what has made the program so successful is our collaborations with many different investigators that have built up a consortium of projects and funding that can add value (and data) to our long term observational effort. We are anxious to have adequate monitoring of ocean acidification return to the full suite of measurements within our existing portfolio.

Best regards,

Dr. Russell R. Hopcroft
Professor of Oceanography
Lead PI, Seward Line and Northern Gulf of Alaska LTER

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center
REFM Division
7600 Sand Point Way N.E.
Seattle, Washington 98115-6349

March 22, 2021

Shiway Wang, PhD
Acting Executive Director
Science Director
Exxon Valdez Oil Spill Trustee Council
4230 University Drive, Suite 220
Anchorage, AK 99508

Re: Continuation and expansion of ocean acidification monitoring in the Exxon Valdez Oil Spill area

I am writing, as a research biologist at NOAA's Alaska Fisheries Science Center and as lead editor of the Gulf of Alaska Ecosystem Status Report (an annual report to the North Pacific Fisheries Management Council), to express strong support for the project entitled "Continuation and expansion of ocean acidification monitoring in the Exxon Valdez Oil Spill area", led by Dr. Hauri. This work will address an important gap in monitoring and understanding of the ecological effects of ocean acidification in the Gulf of Alaska.

The coastal Gulf of Alaska is particularly vulnerable to the effects of ocean acidification and climate change due to its naturally low concentration of carbonate ions and increasing freshwater inputs, which further decrease carbonate ions and therefore its buffer capacity. These conditions push the coastal Gulf of Alaska ecosystem close to and eventually past thresholds that are harmful to calcifying organisms, such as pteropods, crabs and mussels. This low buffer capacity also sets the system up for accelerated decrease in pH, which negatively affects the Pacific Salmon's sensory systems. Taken together, ocean acidification and climate change are likely to have far reaching consequences for the organisms living in the Spill Area, and thereby putting an additional strain on the ecosystem.

Dr. Hauri's proposal to continue and expand the timeseries for ocean acidification parameters are critical to monitor ocean acidification. It will also improve our understanding of the natural variability, which will allow us to detect long-term trends sooner, better constrain biogeochemical models, and as a result, predict with smaller uncertainty how the chemical conditions will change in the future. As such, datasets like the one proposed here are invaluable to ecosystem-based fisheries management in the Gulf of Alaska. Increased understanding and ability to predict how individual species and the marine food web will respond to the effects of ocean acidification is a critical part of managing fisheries in an ecosystem context. A long-term time series and updated ocean acidification model in the Gulf of Alaska would complement NOAA's ocean acidification efforts and would be informative to our annual Ecosystem Status Reports, and to ecosystem-based fisheries management.

Sincerely,

B. Ferriss

Bridget Ferriss
Research Fish Biologist
Resource Ecology and Ecosystem Modeling Program
NOAA Alaska Fisheries Science Center

KODIAK AREA NATIVE ASSOCIATION

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March 26, 2021

Re: Letter of Support for Sustained long-term ocean acidification monitoring in the Northern Gulf of Alaska

To whom it may concern:

This letter is in support of the proposal, "Sustained long-term ocean acidification monitoring in the Northern Gulf of Alaska**" submitted by the University of Alaska Fairbanks under the 2021 Exxon Valdez Oil Spill Trustee Council funding opportunity.**

The Kodiak Area Native Association (KANA) is a 501(c) (3) nonprofit corporation providing health care, social services, and environmental monitoring and programing for the Alaska Native peoples and communities of the Koniag region, including the City of Kodiak and rural village communities of Akhiok, Karluk, Old Harbor, Ouzinkie, Port Lions, and Larsen Bay. Environmental monitoring and programing for the Koniag region is among the services provided by KANA. Our organization believes that healthy individuals live in healthy communities, and our mission to elevate the quality of life of the people we serve guides our decision-making.

Currently, four Tribes in our region are collecting discrete samples in their rural village communities to establish baselines for the Kodiak area. The long term ocean acidification monitoring efforts proposed in this project would benefit the Alaska Native communities in the Koniag region by providing information to better understand the changing habitat of subsistence species. Expanded and sustained monitoring in the Gulf of Alaska would improve the accuracy of ocean chemistry forecast models which can help communities anticipate and plan for changes.

If this project is funded, KANA would collaborate with the project Principle Investigator, Claudine Hauri to exchange knowledge and provide presentations to brief community samplers on ocean chemistry conditions in the Gulf of Alaska and results and findings from the project. This would be an opportunity for two-way exchange of information, including discussion on how open ocean conditions relate to the nearshore environment where our Tribal members are monitoring, observing and conducting subsistence activities.

Sincerely,

M Pfeffer

Mike Pfeffer
Chief Operating Officer and Acting CEO