CSU The California State University
COUNCIL ON OCEAN AFFAIRS, SCIENCE & TECHNOLOGY (COAST)

Graduate Student Research Award Program
AY 2020-2021 Application Form
Application Deadline: Monday, February 1, 2021, 5:00 p.m. PST

Please see information on Graduate Student Research Awards on the COAST **website** and read the **Announcement** for full details and instructions.

Save as both a Word document and a PDF file named as follows: *LastName_FirstName_App.docx* and *LastName_FirstName_App.pdf*. Submit both files as attachments (along with your Department Commitment Form if needed) in **ONE** email to **csucoast@csumb.edu**. Your Advisor must submit your LOR to **csucoast@csumb.edu** separately.

Student Applicant Information

First Name:	Allie (Alexandra)	Last Name:	Margulies
CSU Campus:	San Francisco State	Student ID#:	
Email:		Phone:	
Degree Program:		Degree Sought (e.g., MS, PhD):	MS
Matriculation Date (mm/yy):		Anticipated graduation date (mm/yy):	
GPA in Major Courses:		Thesis-based? (Y/N):	Y

Advisor Information

First Name:	Andrew	Last Name:	Chang
CSU Campus:	San Francisco State	Department:	Biology
Email:		Phone:	

Research Project Title: A decade of extreme climatic events affecting spatiotemporal dynamics of a native foundation species in San Francisco Bay: How can this inform restoration?

Project Keywords (5-7 keywords related to your project): Olympia oyster, rocky intertidal, refuge sites, climate change, environmental stressors, long-term population study

Budget Summary (must add up to $3,000)

Award amount directly to awardee: 3,000

Award amount to Department (DCF required for department funding):	0

The information on this page is for COAST use only and will not be shared with potential reviewers.

Have you previously received a COAST Graduate Student Research Award? (Y/N)	N
If yes, please provide year(s) of award(s):	N/A

Committee Members (Required)

Name	Department	Campus

CSU Suggested Reviewers (Required): Suggested reviewers must be from the CSU. Use the COAST member database to help identify potential reviewers. Do not suggest any reviewers from your campus or reviewers with a potential conflict of interest.

Name:		
CSU Campus:		
Department:		
Email:		

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Please refer to the **Award Announcement** for detailed instructions on the information required for each of the following sections. All the boxes below will expand as you type.

Project Description (65 points total): 1,500-word maximum; any text over this limit will be redacted

INTRODUCTION

The Problem

From 2009 to 2020, California experienced various extreme climatic events including: among the top ten wettest years on record in 2011 [1]; an intense drought from 2012 to 2016 [2]; an unprecedented marine heat wave from 2014 to 2016 [3]; and a record-breaking wet year in 2017 [2]. Extreme climatic events such as these are becoming increasingly prevalent due to climate change [4-6]. Climate extremes can result in major ecological effects such as mortality or changes in ecosystem structure and function [7].

Olympia oysters (*Ostrea lurida*) are an ecologically important foundation species whose success can affect the diversity and abundance of many other taxa [8-10]. China Camp State Park in the San Francisco Bay (SFB) is among the most productive populations in the Olympia oyster's range [11]. By contrast, in years with extreme climatic events this same population has experienced 97% to 100% mass mortality [1,12].

Different extreme climatic events can have harmful or beneficial effects. Low salinity is among the most significant stressors to Olympia oysters in the SFB [13,14]. While prolonged low salinity has been connected to mass mortality events and poor recruitment, high salinity and warm water temperature have been correlated with earlier and higher peak recruitment [12]. Additionally, the presence of multiple simultaneous stressors can interact to intensify biological impacts. For example, low salinity and exposure to high air temperatures may affect oysters concurrently during the spring and interact synergistically to increase mortality [15]. As climate change intensifies temperature extremes and precipitation patterns, exposure to stressful conditions will become increasingly relevant to oyster population success.

The interannual cycling of extreme climatic events can be detrimental: Olympia oyster populations shift upstream during dry, high salinity years, only to be located where low salinity may decimate them during extreme wet winters [12]. This problem is likely to exacerbate. By 2100, climate change projections in California indicate well over a 100% increase in extreme wet events and over a 50% increase in frequency of "climate whiplash" between extreme drought and flooding [16,17].

Refuge from extreme weather?

Benthic organisms such as oysters typically experience less environmental variability downstream in an estuary [18]. This is because conditions closer to the ocean have stronger tidal influence, are more consistently saline, and are less affected by watershed runoff. Downstream conditions also can offer protection from aerial heat stress due to less delayed tides and heavier fog. Therefore, Olympia oysters at downstream sites within the SFB may experience less exposure to stressful environmental conditions during an extreme climatic event. For example, preliminary data analyses indicate that despite being highly productive, China Camp State Park experiences greater

Olympia oyster variability following extreme precipitation than smaller, but more stable populations downstream.

In addition to downstream location, tidal elevation can also affect exposure to environmental stressors [19]. Oysters in lower tidal elevations could exhibit improved survival during air temperature extremes or significant freshwater input. Salinity in the SFB can be highly stratified both vertically and horizontally during high freshwater flows [20]. Therefore, shallow subtidal oysters may experience more muted salinity fluxes. Additionally, subtidal establishment avoids exposure to extreme air temperatures, so subtidal oysters would not face synergistic impacts from these two stressors. Olympia oyster populations appear to recover relatively quickly following a mass mortality event; could subtidal oysters exhibit higher survival during extreme events and provide the larval source to support this rebound?

Significance

Olympia oysters are primary targets of living shorelines projects in the San Francisco Bay because of their substantial decline [21,22], significant ecological role, and shoreline protection benefits in addition to other ecosystem services [23]. Analyzing long-term trends in population success spanning extreme climatic events can identify refuge sites likely to improve the outcome of future restoration. Optimal site selection will support the efficacy and longevity of living shorelines and other oyster restoration projects in the face of climate change as extreme climatic events become increasingly prevalent.

HYPOTHESES

My objective is to determine what impacts have resulted from various extreme climatic events over the past decade and where there are refuges for Olympia oysters in the San Francisco Bay in the face of projected climate change. Analyzing oyster responses to extreme climatic events that occurred throughout the long-term dataset from 2009 to 2021 will reveal spatial patterns of enhanced survival and recruitment at different sites and tidal elevations throughout the SFB.

I hypothesize that:

1. The density and recruitment of Olympia oysters within the San Francisco Bay vary by site from 2009 to 2021.

2. Sites closer to the ocean exhibit more stable populations than sites farther upstream.

3. Compared with shallow subtidal oysters, the density and recruitment of intertidal oysters exhibit a greater decrease following an extreme climatic event.

4. When comparing low salinity events, longer and more severe periods of low salinity in 2017 will correspond with an equal or greater decline of Olympia oysters in the San Francisco Bay than in 2011.

EXPERIMENTAL DESIGN

Overview

I am continuing Olympia oyster monitoring in the SFB which has been conducted by the San Francisco Bay National Estuarine Research Reserve (NERR) and Smithsonian Environmental Research Center (SERC) since 2009. However, this historic monitoring only focuses on intertidal oysters, presenting a data gap on subtidal oysters. One aspect of my project will repurpose SERC's invasive species tracking data by extracting shallow subtidal Olympia oyster settlement data and integrating it with intertidal Olympia oyster data. Subtidal data were primarily collected from panels attached to floating docks at a constant depth of 1.0m. Additional panels were placed at 1.0m below MLLW, while intertidal data have been and will be collected at 0.0m MLLW.

Overall, my approach is to first collect additional data on intertidal Olympia oyster recruitment, density, and size distribution as well as weather and water quality for 2021 using the methodologies outlined below. During this time, I will also work to reconcile historic SERC data and additional environmental data with my primary sources. I plan to manipulate the data to allow for accurate comparisons between years, sites, and datasets. Following this, I can begin to compare oyster population data with environmental trends and apply this to investigate the effects of extreme climatic events and the spatial patterns that indicate refugia.

Data Collection Methodology

Olympia oysters:

Recruitment:

I will collect recruitment data monthly at five sites by deploying three 110cm^2 tiles per site as settlement surfaces for recruits. Tiles shall be placed rough side down on PVC frames at 0.0m MLLW. Approximately once a month, tiles shall be recovered and replaced. I will use a dissecting microscope in the laboratory to count monthly recruitment, calculated as recruits per square meter per day deployed.

Density and Size Distribution:

Each winter and spring, I will measure population density and size distribution during low tide at ten sites. Surveys shall be conducted along permanent 30m transects at 0.0m MLLW. I will place ten quadrats at random points along the transect. Within each quadrat I will count the total number of oysters. To measure size distribution, the length of the first ten oysters counted in each quadrat is measured to the nearest millimeter using calipers.

Environmental Conditions:

I will use site-specific data and regional sources to determine the spatial trends in environmental stressors oysters encountered throughout the study period. At each recruitment site, data loggers (TidbiT and TidbiT v2, Onset Computer, Bourne, Massachusetts) are attached to the PVC frames at 0.0m MLLW. In addition to site-specific TidbiT data, I will analyze water quality including salinity, temperature, dissolved oxygen, pH, and turbidity using data from the Estuary and Ocean Science Center's Coastal Observations and Monitoring Science stations. Water quality data are reported at 15-minute intervals.

Data Analysis Plan

Data analyses will be conducted using R (4.0.3), RStudio [24], and the lme4 [25] and ggplot2 packages [26]. My data analysis plan for each hypothesis is as follows:

1. Site Spatial Analysis:

   To compare how study sites vary over time in density and recruitment I will use a generalized linear mixed model with timepoint as a random factor.

2. Site Stability:

   To determine the variability of density and recruitment within each site I will use a multivariate generalized linear mixed model. I will compare each site's values to its distance from the mouth of the bay.

3. Intertidal versus Subtidal:

   To compare density and recruitment of intertidal versus subtidal oysters following extreme climatic events I will use a two tailed t-test. These measures will be adjusted to account for differences in baseline levels.

4. Low Salinity Severity:

   First, I will compare the duration and severity of low salinity in the study area in 2011 versus 2017 using thresholds of 5 psu and 10 psu [27]. Then, to compare the difference in exposure between years I will run independent 2 sample t-tests for each salinity level. To determine if oyster abundance exhibited an equal or greater change following extreme weather in 2017 versus 2011, I will run an independent 2 sample t-test for the time frame during and after low salinity events.

References (0 points): no limit

[1] Cheng, B. S., A. L. Chang, A. Deck, and M. C. Ferner. 2016. Atmospheric rivers and the mass mortality of wild oysters: insight into an extreme future? Proceedings of the Royal Society B 283:20161462. http://dx.doi.org/10.1098/rspb.2016.1462.

[2] Wang, S. Y. S., J. H. Yoon, E. Becker, and R. Gillies. 2017. California from drought to deluge. Nature Climate Change 7:465-468.

[3] Jacox, M. G., M. A. Alexander, N. Mantua, and J. D. Scott. 2018. Forcing of multiyear extreme ocean temperatures that impacted California Current marine resources in 2016. Bulletin of the American Meteorological Society 99:27-33.

[4] Easterling, D. R., G. A. Meehl, C. Parmesan, S. A. Changnon, T. R. Karl, and L. O. Mearns. 2000. Climate extremes: observations, modeling, and impacts. Science 289:2068-2074. doi:10.1126/science.289.5487.2068.

[5] Coumou, D. and S. Rahmstorf. 2012. A decade of weather extremes. Nature Climate Change 2:491-496. doi:10.1038/nclimate1452.

[6] IPCC. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

[7] Smith, M. D. 2011. An ecological perspective on extreme climatic events: a synthetic definition and framework to guide future research. Journal of Ecology 99:656-663. doi: 10.1111/j.1365-2745.2011.01798.x.

[8] Coen, L. D., R. D. Brumbaugh, D. Bushek, R. Grizzle, M. W. Luckenbach, M. H. Posey, S. P. Powers, and S. G. Tolley. 2007. Ecosystem services related to oyster restoration. Marine Ecology Progress Series 341:303-307.

[9] Scyphers, S. B., S. P. Powers, K. L. Heck Jr, and D. Byron. 2011. Oyster Reefs as Natural Breakwaters Mitigate Shoreline Loss and Facilitate Fisheries. PLoS ONE 6:e22396. doi:10.1371/journal.pone.0022396.

[10] Ramsay, J. 2012. Ecosystem services provided by Olympia oyster (*Ostrea lurida*) habitat and Pacific oyster (*Crassostrea gigas*) habitat: Dungeness crab (*Metacarcinus magister*) production in Willapa Bay, WA. Final report submitted to Oregon State University.

[11] Wasson, K., B. B. Hughes, J. S. Berriman, A. L. Chang, A. K. Deck, P. A. Dinnel, C. Endris, M. Espinoza, S. Dudas, and M. C. Ferner. 2016. Coast-wide recruitment dynamics of Olympia oysters reveal limited synchrony and multiple predictors of failure. Ecology 97:3503-3516.

[12] Chang, A. L., A. K. Deck, L. J. Sullivan, S. G. Morgan, and M. C. Ferner. 2016. Upstream—downstream shifts in peak recruitment of the native Olympia oyster in San Francisco Bay during wet and dry years. Estuaries and Coasts 41:65-78. https://link.springer.com/article/10.1007%2Fs12237-016-0182-1.

[13] Zabin, C. J., S. Attoe, E. D. Grosholz, and C. Coleman-Hulbert. 2010. Shellfish conservation and restoration in San Francisco Bay: opportunities and constraints: final report for the Subtidal Habitat Goals Committee. Chapter 7. Oakland, CA. http://www.sfbaysubtidal.org/PDFS/07-Shellfish.pdf.

[14] Wasson, K., C. Zabin, J. Bible, E. Ceballos, A. Chang, B. Cheng, A. Deck, E. Grosholz, M. Latta, and M. Ferner. 2014. A guide to Olympia oyster restoration and conservation: environmental conditions and sites that support sustainable populations in central California. San Francisco Bay National Estuarine Research Reserve. www.oysters-and-climate.org.

[15] Bible, J. M., B. S. Cheng, A. L. Chang, M. C. Ferner, K. Wasson, C. J. Zabin, M. Latta, E. Sanford, A. Deck, and E. D. Grosholz. 2017. Timing of stressors alters interactive effects on a coastal foundation species. Ecology 98:2468-2478.

[16] Yoon, J. H., S. Y. S. Wang, R. R. Gillies, B. Kravitz, L. Hipps, and P. J. Rasch. 2015. Increasing water cycle extremes in California and in relation to ENSO cycle under global warming. Nature Communications 6:9657. doi:10.1038/ ncomms9657.

[17] Swain, D. L., B. Langenbrunner, J. D. Neelin, and A. Hall. 2018. Increasing precipitation volatility in twenty-first-century California. Nature Climate Change 8:427-433. https://doi.org/10.1038/s41558-018-0140-y.

[18] Laprise, R., and J. J. Dodson. 1993. Nature of environmental variability experienced by benthic and pelagic animals in the St. Lawrence Estuary, Canada. Marine Ecology Progress Series 94:129-139.

[19] Garrison, T. 2015. Essentials of Oceanography, Seventh Edition. Chapter 14: Benthic Communities. Cengage Learning. Stamford, CT.

[20] Cloern, J. E. 1984. Temporal dynamics and ecological significance of salinity stratification in an estuary (South San Francisco Bay, USA). Oceanological Acta 1984. 7:137-141.

[21] Beck, M. W., R. D. Brumbaugh, L. Airoldi, A. Carranza, L. D. Coen, C. Crawford, O. Defeo, G. J. Edgar, B. Hancock, M. C. Kay, H. S. Lenihan, M. W. Lukenbach, C. L. Toropova, G. Zhang, and Z. Guo. 2011. Oyster reefs at risk and recommendations for conservation, restoration, and management. BioScience 61:107-116.

[22] Zu Ermgassen, P. S. E., M. D. Spalding, B. Blake, L. D. Coen, B. Dumbauld, S. Geiger, J. H. Grabowski, R. Grizzle, M. Luckenbach, and K. McGraw. 2012. Historical ecology with real numbers: past and present extent and biomass of an imperiled estuarine habitat. Proceedings of the Royal Society B: Biological Sciences 279:3393-3400.

[23] Boyer, K., C. Zabin, S. De La Cruz, E. Grosholz, M. Orr, J. Lowe, M. Latta, J. Miller, S. Kiriakopolos, C. Pinnell, D. Kunz, J. Moderan, K. Stockmann, G. Ayala, R. Abbott, and R. Obernolte. 2017. San Francisco Bay Living Shorelines: Restoring Eelgrass and Olympia Oysters for Habitat and Shore Protection. Chapter 17 in D. M. Bilkovic, M. Mitchell, J. Toft, and M. La Peyre, eds., Living Shorelines: The Science and Management of Nature-Based Coastal Protection. CRC Press Marine Science Series.

[24] RStudio Team. 2021. RStudio: Integrated Development for R. RStudio, PBC, Boston, MA. http://www.rstudio.com/.

[25] Bates, D., M. Mächler, B. Bolker, and S. Walker. 2015. Fitting linear mixed-effects models using lme4. Journal of Statistical Software 67:1-48. doi: 10.18637/jss.v067.i01.

[26] Wickham, H. 2016. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York. ISBN 978-3-319-24277-4. https://ggplot2.tidyverse.org.

[27] Cheng, B. S., J. M. Bible, A. L. Chang, M. C. Ferner, K. Wasson, C. J. Zabin, M. Latta, A. Deck, A. E. Todgham, and E. D. Grosholz. 2015. Testing local and global stressor impacts on a coastal foundation species using an ecologically realistic framework. Global Change Biology 21:2488–2499.

[28] State Coastal Conservancy. 2010. San Francisco Bay Subtidal Habitat Goals Report. http://www.sfbaysubtidal.org/report.html.

[29] Gedan, K. B., L. Kellogg, D. L. Breitburg. 2014. Accounting for multiple foundation species in oyster reef restoration benefits. Restoration Ecology 22:517-524.

[30] Grabowski, J. H. and C. H. Peterson. 2007. Restoring oyster reefs to recover ecosystem services. Pages 281–298 in Cuddington K, Byers J, Wilson W, Hastings A, eds. Ecosystem Engineers: Plants to Protists. Academic Press.

[31] Wasson, K., C. Zabin, J. Bible, S. Briley, E. Ceballos, A. Chang, B. Cheng, A. Deck, E. Grosholz, A. Helms, M. Latta, B. Yednock, D. Zacherl, and M. Ferner. 2015. A guide to Olympia oyster restoration and conservation: environmental conditions and sites that support sustainable populations. Elkhorn Slough National Estuarine Research Reserve. www.oysters-and-climate.org.

[32] Grabowski, J. H., R. D. Brumbaugh, R. F. Conrad, A. G. Keeler, J. J. Opaluch, C. H. Peterson, M. F. Piehler, S. P. Powers, and A.R. Smyth. 2012. Economic valuation of ecosystem services provided by oyster reefs. Bioscience 62:900-909.

Timeline (10 points total): 250-word maximum

Prior to COAST: October 2020 - May 15, 2021: I completed winter oyster surveys in December 2020, and I participate in monthly retrieval and deployment of recruitment tiles as well as environmental data collection and data entry.

May 15, 2021- October 2021: During this time, I will count oyster recruitment tiles as needed in the laboratory and complete field work including spring oyster surveys and monthly collection of environmental and oyster recruitment data. I will reconcile SERC data with intertidal oyster data and compile environmental data for comparison with oyster population trends. In addition, I will complete and submit my thesis prospectus.

November 2021 - May 2022: Throughout this period, I will complete winter oyster surveys and monthly field work while continuing to enter and analyze monthly data. I will incorporate these data into my previous analyses and complete a draft thesis manuscript. I also plan to present at a conference during this time.

June 2022 - November 2022: In this timeframe I will finalize my thesis manuscript and prepare a paper to publish in an academic journal.

December 2022: Anticipated thesis defense and graduation from San Francisco State University.

Need for Research (NEW SECTION, 7 points total): 250-word maximum

The State Coastal Conservancy identified Olympia oysters as a primary target for restoration, proposing a 3,200 hectare increase over 50 years [28]. As a foundation species [29], stable Olympia oyster populations translate to a more diverse, healthy ecosystem that provides important ecosystem services [30]. To maximize these benefits, restoration projects must be well supported by data and best available science. Some of this study's sites have already been recommended for restoration or conservation [14,31]. This research will indicate which of these sites and elevations should be prioritized to offer refuge from climate change.

With the projected increase in extreme climatic events, understanding the impacts of extreme weather and identifying refuge locations will become increasingly vital to ensuring the success of an important foundation species like Olympia oysters. This study continues the long-term monitoring of Olympia oysters by the NERR and SERC and builds off their previous research. While previous studies have utilized portions of this dataset in isolation, no other study has utilized these long-term data to the fullest potential by analyzing the entire time frame across multiple projects, and refuges have not been explicitly considered. This dataset is unique in that it includes both biological and physical data and encompasses a period of multiple unprecedented extreme climatic events which have not been studied with relation to Olympia oysters. Additionally, few ecological studies have assessed the interactive impacts of different extreme climatic events due to lack of opportunity [7], and this project makes use of such an opportunity.

Relevance to state of California (NEW SECTION, 3 points total): 100-word maximum

Olympia oysters, the only oysters native to California, engineer high-value habitat for countless other native species. Additionally, oysters benefit millions of Californians through ecosystem services such as wave attenuation, water filtration, shoreline stabilization, and habitat provisioning, which are valued at $5,500 to $99,000 per hectare per year [32]. This research will provide information critical to advancing Olympia oyster restoration success, bringing an economic value to Californians by improving protection of property, infrastructure, and water quality in an intensely developed area. Additionally, this research will help support the ecological health of the San Francisco Bay as climate change progresses.

Budget and Justification (15 points total)

Example Budget (feel free to erase the content and use this format, adding additional rows as necessary, or create your own):

Item/Description	**Unit Price**	**Quantity**	**Amount to Awardee (via Financial Aid)**	**Amount to Department**
Car Insurance	$106.07 / month	6 months	$636.42	-
Health Insurance	$375 / month	6 months	$2,250	-
Transportation	$0.56 / mile	202.8 miles	$113.58	-
		Subtotals:	*$3,000.00*	*$0.00*
		Grand Total	**$3,000.00**	

Justification (250-word maximum):

Being awarded $3,000 from COAST would help me to conduct my research more efficiently. Since my acceptance to San Francisco State University, I have strongly considered getting a part-time job to help cover necessary monthly expenses such as car and medical insurance. While my student fees cover basic medical care, additional coverage is necessary for emergencies that might require hospitalization. This is especially important amid a pandemic, as well as for completing field work where accidental injury could occur. Car insurance is necessary for my travel to field sites as well as the laboratory, and the remaining funds would support the cost of transportation to study sites once I am no longer funded by my mentors, beginning in summer 2021.

Without COAST funding, working a part-time job would require a significant time commitment and a restrictive schedule that could interfere with intertidal field work, which must occur during low tide. An award of $3,000 could make up for approximately 50 days and nights of part-time work, relieving me of a significant time commitment. COAST funding would allow me to focus that extra time and energy on my research, rather than financing critical expenses. This would support my ability to effectively collect data, complete lab work, finish my degree faster, and ultimately advance scientific understanding of how an important native species can be supported in the face of climate change.

Application Deadline: Monday, February 1, 2021, 5:00 p.m. PST
Save as both a Word document and a PDF file named as follows:
***LastName_FirstName_App.docx* and *LastName_FirstName_App.pdf*.**
Submit both files as email attachments in ONE email to csucoast@csumb.edu.

Within 24 hours of application submission, you will receive a confirmation email from COAST. Please save this confirmation email for future reference. If you do not receive a confirmation email, please contact Kimberly Jassowski (kjassowski@csumb.edu) to ensure your application was received.