I. Project Title: Opportunistic Assessment of El Niño Effects on Marine Population Connectivity

II. Abstract: I aim to test if El Niño oceanographic conditions drive the poleward geographic range expansion of coastal marine species, using as a case study the kelp forest gastropod Kellet's Whelk (*Kelletia kelletii*). Kellet's whelk is a predatory marine snail, the target of an escalating fishery, and one of numerous species implicated in the hypothesis that warm northward-flowing ocean currents generated by El Niño transport fish and invertebrate larva up the coast from Mexico and the Southern California Bight to central California, making northern reefs dependent on southern populations for new supplies of recruits. This summer, following the 2015-16 El Niño, I will conduct SCUBA-based population density and size-frequency surveys of Kellet's whelk across the species' range. I will combine my data with pre-El Niño data collected last summer and data from the 1997-98 El Niño, and test for enhanced larval recruitment at the poleward margin of the species' range following El Niño. I will be advised by Dr. Crow White, and will collaborate with scientists in southern California and Mexico. I will learn and conduct experimental design, scientific diving, statistics, and written and oral communication of international marine ecology research. I expect my research will advance scientific understanding of marine population dynamics, and guide fisheries management in relation to climate change.

III. Introduction: This project will leverage the 2015-16 El Niño with SCUBA-based marine biology surveys along the U.S. and Mexico west coast to assess the driving effects of El Niño events on the poleward range expansion of marine species. More broadly, my research is designed to answer a long-standing question in marine ecology with significant management and conservation implications: From where does the next generation of fish and shellfish originate?

Nearly all of the marine fish and shellfish living along coastlines release microscopic larvae into the open ocean. The larvae then disperse for weeks (e.g., abalone) to months (e.g., rockfish) to nearly a year (e.g., lobster) before settling back into coral reefs and kelp forests (1). The larvae are too small and they travel too far to be tracked directly (2, 3). Yet, knowing where they go is important for conservation and management, because the extent to which the next generation of fish and shellfish at a reef is from elsewhere effects how dependent it is on other populations for its replenishment. Understanding these patterns of "connectivity" and "dependency" among reefs is critical for determining how to best protect, fish and manage our coastlines (4-6).

To complicate matters, connectivity patterns change annually (7). An example of such changes along the Pacific Coast of North America has to do with El Niños, which occur every few

years and generate warm, northward-flowing ocean currents able to transport marine larva up the coast (8-10). Thus, it is hypothesized that El Niños can make northern reefs dependent on southern populations for new supplies of fish and shellfish (11-14). However, observed ecological responses to El Niños have been variable (15-17), leaving the hypothesis unresolved. This hypothesis has strong societal relevance because El Niños are predicted to increase in frequency and intensity with climate change (18, 19), and because strategic management of fisheries in relation to effects of El Niño on connectivity could produce large gains in catches and profit (20). Such present and future implications of El Niño events highlights the importance in studying them now when they occur.

I aim to elucidate these patterns of connectivity along the California U.S and Baja, Mexico coastline, with particular focus on how El Niño events drive poleward range expansion by connecting southern spawning grounds with northern recruitment areas. I will focus on the kelp forest marine snail Kellet's whelk (*Kelletia kelletii*) for several key reasons: **1)** It is a significant predator and emerging fisheries species, and thus of ecological and economic importance. **2)** Kellet's whelk is in the process of expanding its range up the California coast (12, 21). **3)** It shares its historic range, kelp forest habitat (Figure) and key life history traits with many other important marine species such as spiny lobster, kelp bass and sheephead (22). Thus, Kellet's whelk's range expansion may be an indicator of future expansions in other species as the frequency and intensity of El Niño events increases. Finally, **4)** there is the opportunity to integrate the data I collect with archived data, including "control" non-El Niño data, to generate a complete data set for testing my hypothesis. The archived data consists of population surveys conducted in 2015, prior to the current El Niño, and conducted before and after the 1997-98 El Niño (12). Analysis of these 1997-98 and 2015-16 pairs of data provides a robust and replicated (for enhanced statistical power) experimental design for testing how spatial patterns of larval recruitment respond to El Niño.

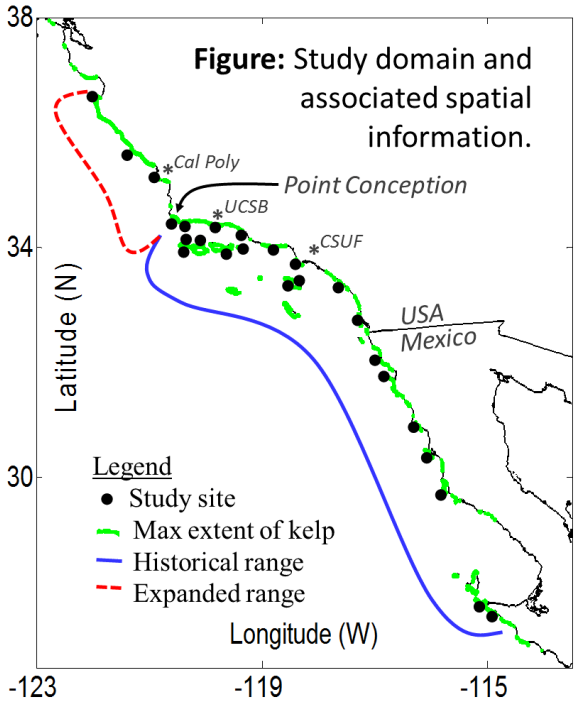

Figure: Study domain and associated spatial information.

IV. Objective: 1) Test for enhanced larval recruitment of Kellet's whelk in the species' poleward, expanded range following an El Niño, and 2) provide insight on whether El Niño events drive

poleward connectivity and range expansion in marine species.

V. Methods: I will work alongside advisor Dr. White in all research activities, and will partner with scientists at California State University, Fullerton (CSUF) and Universidad Autónoma de Baja California, Ensenada, Mexico (UABC). We will access 25 kelp forest study sites via boat-supported scientific SCUBA diving (Figure). At each site, we will quantify whelk recruitment patterns via size-specific population density surveys conducted along fixed-width transect lines (following 23).

I will organize the data I collect plus the archived data into a twice-replicated before-after, control-impact experimental design (2N BACI). Representing "before" and "after" responses in the "impact" region, the 2015 pre-El Niño survey data from Kellet's whelk's expanded range will be paired (site-to-site) with my 2016 post-El Niño survey data from the expanded range, and, similarly, the pre- and post- 1997-98 El Niño data from the expanded range will be paired as well. Representing the "control" region, where El Niño events are not predicted to enhance recruitment as much as in the expanded range, the 1997-98 and 2015-16 survey data from Kellet's whelk's historic range will be paired. The outcome is a 2N BACI in relation to two El Niño events. I will apply a repeated measured Analysis of Variance (ANOVA) to the data to test the hypothesis: Recruitment is disproportionately enhanced in the species' expanded range following an El Niño.

VI. Timeline: #

June-August 2016: Conduct field research. #

August-October 2016: Organize data and perform statistical analysis. #

October-November 2016: Create scientific poster and present at national conference. #

November 2016-March 2017: Write study and results into senior thesis and scientific publication. #

VII. Final Project and Dissemination: I aim to present my research at the Western Society of Naturalists annual meeting in November 2016, and at a Cal Poly Biology Department seminar dedicated to student projects. I also will compile my research for my senior thesis project at Cal Poly, and will develop my results into a scientific paper for publication in a peer-reviewed journal. These products will be generated with advising from Dr. White and in partnership with professors and students at CSUF and UABC. I expect my presentations, thesis and publication to educate and inform students, scientists and managers in marine science and fisheries management.

VIII. Budget Justification: Because of his previous research, Dr. White will make available for my project all the required major equipment and most necessary research supplies. Baker-Koob Endowment funds will be used only to purchase replacement supplies, and to partially support lodging, meals and operating expenses (fuel) required to access the study sites.

Proposal Budget Sheet (

Student Applicant(s): Justin Gerard Palmer	
Faculty Advisor: Dr. Crow White	
Project Title: Opportunistic Assessment of El Nino Effects on Marine population Connectivity	**Requested Endowment Funding**
Travel *subtotal*	**$400**
Travel: In-state (lodging and meals)	**$400**
Travel: Out-of-state	**$0**
Travel: International	**$0**
Operating Expenses *subtotal*	**$ 1410**
Non-computer Supplies & Materials	
Dive Slate	**$30**
Marker Buoys (x2)	**$70**
Transect Tapes (x4)	**$160**
SCUBA tank refills	**$250**
Research Truck Fuel	**$350**
Research Boat Fuel	**$550**
Computer Supplies & Materials	**$0**
Software/Software Licenses	**$0**
Printing/Duplication	**$0**
Postage/Shipping	**$0**
Registration	**$0**
Membership Dues & Subscriptions	**$0**
Multimedia Services	**$0**
Advertising	**$0**
Journal Publication Costs	**$0**
Contractual Services *subtotal*	**$0**
Contracted Services	**$0**
Equipment Rental/Lease Agreements	**$0**
Service/Maintenance Agreements	**$0**
TOTAL	**$1810**

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CAL POLY
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22 April 2016

To the Warren J. Baker and Robert D. Koob Endowments Student Selection Committee:

I am very pleased to write this letter of recommendation for Mr. Justin Palmer and his proposed research project on the spatial population dynamics and range expansion of Kellet's whelk. Justin is an undergraduate Biology major here at Cal Poly, where he is working under my supervision on a research project examining recruitment patterns of the marine gastropod Kellet's whelk across the species biogeographic range and in relation to El Niño oceanographic conditions.

Since meeting Justin in the fall of 2015, and since then working with him in the lab, I have been enormously impressed with Justin's intellect, hard work, creativity, and productivity. **I consider Justin a very talented and motivated student with great promise as a developing scientist**.

Justin first started working in my lab using an image software program in order to analyze photo-quadrat surveys of Kellet's whelk egg masses that we conducted the previous summer. Justin immediately impressed me by teaching himself (and me!) the image software program and how to use it most efficiently. He then went on to clearly organize the hundreds of photo-quadrat files I gave him and systematically and meticulously analyze them. The analysis required careful delineation of egg mass boundaries, counting of egg capsules and, the most technical part, rescaling the image to common units. Justin was very careful and reliable in all of these activities, and, importantly, he documented his work clearly with excellent notes.

Justin really began to shine in my lab when he started thinking beyond his immediate research task to the bigger picture of the project and how he could contribute to understanding Kellet's whelk's range expansion. In my lab meetings Justin greatly impressed me in his mature and clear explanation of how the photo-quadrat survey data analysis that he was performing contributed to the quantification of geographic variation in reproductive output, and how that information contributed to understanding potential rates of migration between our study sites. **More than any other student in my lab, Justin is able to connect the dots between the basic analysis he is conducting in the lab and bigger picture research questions he would like to answer.**

Justin further impressed me by coming to my office and proposing that he join my summer field research team in order to improve our photo-quadrat survey methodology and test for El Niño effects on recruitment. He was identifying problems and providing solutions to enhancing the efficiency and accurate of my lab's research, while also aiming for a bigger-picture goal of testing a hypothesis of ecological and socioeconomic importance. It is this characterization of Justin that sets him apart from many of the other students in my lab.

Justin is currently taking my class MSCI 439: Fisheries Science and Resource Management. Already, Justin has proved himself to be an astute student. I am in particular impressed with his ability to synthesize multiple class lessons into understanding a more complex problem in fisheries management. For example, just last week Justin helped explain to the entire class how differential growth rates of fish species interact with the fishing history of these species to explain why scientists

have observed complex and highly variable stock recovery trends of the different species following their protection in no-fishing marine reserves. Justin is currently earning an "A" in the class.

The Baker-Koob project proposed by Justin is both experimentally sound and with clear potential to advance the science of meta-population ecology, and conservation and management of fisheries species along the California coast. Using Kellet's whelk as a case study, Justin seeks to test a hypothesis – that El Niño can drive for increased recruitment along the central California coast – with broad implications across a suite of sub-tropical species and in relation to Climate Change. Given Justin's attention to detail, self-motivation and critical thinking, I am fully confident that he has the ability to carry out the methods outlined in his proposal, and meet the objectives of his project. Of note, his project carefully builds on the previous population ecology research conducted by myself and one of my key collaborators, Dr. Danielle Zacherl (who will be mentoring Justin as well). In particular, Justin is utilizing archived survey data collected by my and Dr. Zacherl's labs, enabling him to achieve an enhanced level of statistical power for testing his hypothesis. For these reason, I believe Justin will succeed in his project and I very much look forward to advising him on it and seeing the results.

The marine science facilities, equipment and supportive roles at Cal Poly and in my lab fully meet the needs of Justin and his proposed research project. Justin will conduct the field surveys with the support of my lab's field research team, existing supplies, and Cal Poly's research vessel and vehicles. As stated in his proposal, Baker-Koob funds are required only for some replacement supplies, and travel and operating expenses of our boat and vehicles. Once back on campus, my lab space and facilities (e.g., computer) and my advising will enable Justin to successfully carry out his proposed statistical analyses. I also will advise him in organizing his study into research presentations (e.g., at the Western Society of Naturalists conference) and publications (thesis and in a peer-reviewed journal). Over all, I am very excited about Justin's project, and will provide extensive advising to him throughout its development, as well as leadership in keeping track of the budget and supplies purchases. I also will facilitate Justin's mentoring from my collaborators Dr. Zacherl at CSU Fullerton and Dr. Cira Gabriela Montaño Moctezuma at Universidad Autónoma de Baja California in Ensenada, Mexico.

Justin is a great pleasure to work with and he has become an important member of my lab. He has great potential to become a creative, ambitious scientist. His well-thought out proposed project on Kellet's whelk population ecology is yet another example of his promise as a developing scientist, and I am fully supportive of his project and enthusiastic to watch it and Justin's career develop successfully. For all of these reasons, **I give him my highest recommendation** for support from the Warren J. Baker and Robert D. Koob Endowments.

Sincerely,

Crow White, Ph.D.
Assistant Professor of Biological Sciences