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

Graduate Student Research Award Program
AY 2018-2019 Application Form

Application Deadline: Thursday, January 31, 2019, 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 to graduate@share.calstate.edu.

Student Applicant Information

First Name:	Blair	Department or Degree Program:	Fisheries Biology
Last Name:	Winnacott	GPA in Major Courses (If first semester as a graduate student, please enter, "n/a, first semester".):	
Student ID#:		Matriculation date (mm/yy):	
CSU Campus:	Humboldt State University	Anticipated graduation date (mm/yy):	
Email:		Degree Sought (e.g., MS, PhD):	MS
Phone:		Thesis-based? (Y/N):	Y

Advisor Information

First Name:	Eric	Position/Title:	Adjunct Faculty-Research Fisheries Biologist-National Marine Fisheries Service
Last Name:	Bjorkstedt	Email:	Eric.Bjorkstedt@noaa.gov
CSU Campus:	Humboldt State University	Phone:	707-826-3688
Department:	Fisheries Biology		

Research Project Title:	Assemblage Structure and Cross-Shelf Distribution of Larval Rockfish (*Sebastes*) off Northern California
Project Keywords (5-7 keywords related to your project):	Rockfishes, Climate Variability, Northern California, Larval Fish Distributions, Trinidad Head Line, Upwelling Fronts

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

Award amount directly to awardee:	
Award amount to Department:	3000

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):	

Suggested Reviewers (Required)

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.

Project Description (60 points total)-1,500 word maximum; any text over this limit will be redacted

Introduction

The genus *Sebastes* (the rockfishes) is a speciose group of marine fishes supporting important commercial and recreational fisheries off the west coast of the United States (Love et al. 2002). The rockfishes represent one of the most diverse fish assemblages off the coast of California, with roughly 45 species found off northern California (Love et al. 2002). *Sebastes* is characterized by viviparous reproduction, producing larvae at the first-feeding stage and ranks as one of the most abundant ichthyoplankton captured in plankton nets off northern and southern California (Doyle 1992, Moser 1996). Due to their high frequency of occurrence in plankton surveys and their economic and ecological importance, rockfish larvae have received considerable attention in fisheries research. Recently, larval rockfish sampling has been used to define spawning habitat of adult rockfish as well as assess the effectiveness of marine reserves in protecting habitat for spawning adults (Thompson et al. 2016, 2017). Assessments of larval rockfishes may provide an alternate means of evaluating general trends in rockfish populations that avoids potentially lethal sampling of adults (e.g., by hook-and-line fishing or trawling), especially in protected areas.

Although very abundant, identifying larval rockfish to species is difficult due to limited unique morphological characteristics and the large number of species (Moser 1996). The difficulty in identifying their larval stage to species has limited our knowledge and ability to examine rockfish populations off northern California. As few studies have focused on larval rockfishes to the species level, their seasonality, distributions, and response to environmental fluctuations are poorly understood. Rockfish parturition varies seasonally. One broadly defined group of species releases larvae in the winter and early spring and another during the spring and early summer (Wyllie-Echevarria 1987, Lenarz et al. 1995). Parturition timing in the rockfishes tends to occur later in the year with increasing latitudes, a result of the variation in the timing of oceanic conditions (e.g., upwelling) between latitudes (Laidig 2010, Wyllie-Echevarria 1987). Resolving seasonal variability in the larval rockfish assemblage will provide information relevant to assessing how species will respond to climate change, whether by changes in reproductive success or shifts in reproductive timing.

Cross-shelf distributions of larval rockfish are likely to broadly reflect the distribution of adult stocks, and have been shown to be influenced at smaller scales by upwelling fronts (Bjorkstedt et al. 2002). As well as influencing the spatial distribution of larval and juvenile rockfish, fronts have been shown to influence settlement patterns of juvenile rockfish to nearshore habitats and may be an important factor in the transport of early life history stages of rockfishes (Woodson et al. 2012). Species-specific and seasonal distributions of larval rockfish and their association with fronts may be an important factor to consider when designing surveys targeting larval rockfish. Better information on seasonal and species-specific distributions is needed to link adult and larval distributions and to identify any differences in species' distributions relative to water mass and hydrographic structure.

Fluctuations in the physical environment of the California Current has becoming increasingly common, most likely reflecting climate change, and how the early life history stages (ELHS) of rockfishes will respond to climate variability is poorly understood. Studies have identified local and basin-scale climate variability as the primary drivers of change in assemblage structure. Off northern and central California, negative anomalies in sea level, associated with equatorward alongshore flow, has been associated with increased survival, abundance, and recruitment of juvenile rockfish (Ralston et al. 2013). Laidig (2010) correlated latitudinal differences in the timing of parturition and settlement of juvenile blue rockfish (*Sebastes mystinus*) to the latitudinal differences in the timing of upwelling. An understanding of the mechanisms that affect recruitment (ELHS) of rockfishes is needed to anticipate changes in their population dynamics and distributions due to climate change.

Thesis Project

The larval rockfish assemblage off northern California has never been characterized and it is unknown what species comprise this assemblage and how they're distributed along the continental shelf and shelf break. Our knowledge of the larval rockfish assemblage is limited to the genus level (*Sebastes*) and we can only infer how the abundance, distributions, and seasonal spawning of this group as a whole is broadly influenced by the California Current. Characterizing the community structure of larval rockfish off northern California, determining seasonal and interannual variability, and their relative abundance over time may be useful information for fisheries managers. The purpose of this study is to describe the cross-shelf distributions of larval rockfish and the seasonal and interannual changes in the larval rockfish assemblage off northern California. I hope to relate changes in assemblage structure to environmental variability and identify the role of this variability in influencing the larval rockfish assemblage. Specifically, the questions I hope to ask: (i) How has the larval rockfish assemblage changed over the given study period (2009-2019), in the context of interannual and season variability? (ii) How are larval rockfish distributed across the continental shelf and slope? (iii) Can environmental variability explain patterns in the larval rockfish assemblage?

Objectives

My objectives for this study are to:

(i) Develop a fishery-independent time series (2009-2019) on larval rockfish dynamics off northern California
(ii) Characterize the larval rockfish assemblage of the Trinidad Head Line and determine the seasonal and interannual variability in assemblage structure
(iii) Characterize the cross-shelf distributions of larval rockfish in the context of ocean structure
(iv) Determine whether changes in assemblage structure correlate with local and basin-scale indices of climate variability

Methods

Sampling Site

Larval rockfish will be collected from the Trinidad Head Line, a cross-shelf transect and time-series that has been taking environmental data and zooplankton samples since 2006 (Figure 1). The Trinidad Head Line is located due west of Trinidad, California. The transect is occupied by six stations,

three of which are located over the continental shelf and the additional three stations located over the shelf break.

Sample Collection

Zooplankton samples are collected from a 505 μm and 335 μm mesh bongo net towed obliquely from a depth of 5 meters above the sea floor at shallow stations and to 100 meters at deeper stations. This study will focus on ethanol preserved samples collected from the years 2009-2019 during winter cruises (January, February, and March) and spring-summer cruises (May, June, and July) to assess seasonal variability. Environmental data is also collected using a CTD instrument to gather temperature, salinity, fluorescence, and dissolved oxygen concentration. In the lab, larval rockfish will be sorted from zooplankton samples for later genetic identification.

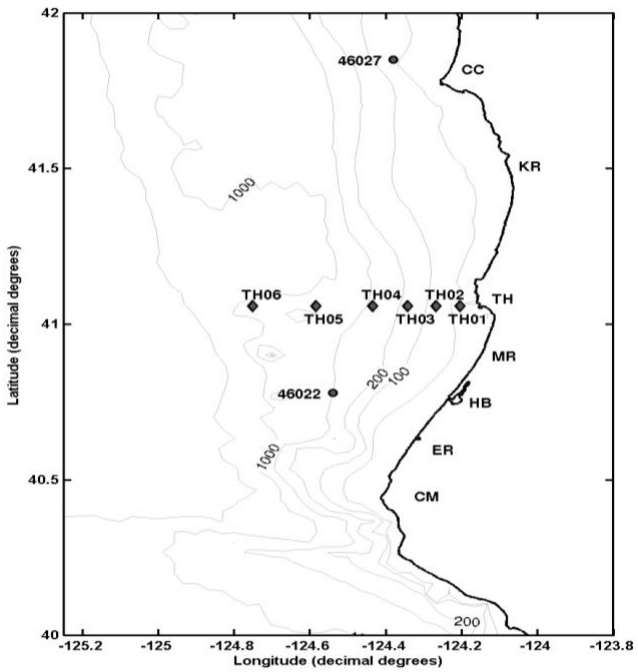

Figure 1. Trinidad Head Line. Stations (diamonds) are numbered TH01 (most inshore) to TH06 (most offshore). Landmarks are Crescent City/Point St. George (CC), Trinidad Head (TH), and Cape Mendocino (CM). Circles indicate positions of NDBC Buoys 46027 and 46022. Grey contours indicate 50 m, 100 m, 200 m, 500 m, 1000 m, and 2000 m isobaths.

Species Identification

Given the difficulties in identifying larval rockfish to species, genetic identification will be required to conduct this study. Genetic identification will be conducted by sequencing the cytochrome *b* gene and comparing the subsequent sequence to an existing reference database of adult rockfish.

Analysis

Overview of Assemblage- My first goal will be to characterize the larval rockfish assemblage from the Trinidad Head Line by determining relative abundance of species and proportions of stations occupied by each species. The relative abundance of each species will be standardized using a standard haul factor (SHF, i.e. larval count x (tow depth/volume of water filtered x 10)), expressed as the abundance of larvae under $10m^2$ of sea surface area, to account for differences in depth and tow length among stations (Smith and Richardson 1977).

Interannual and Seasonal Variability- To evaluate and visualize interannual and seasonal variability of the larval rockfish assemblage, a nonmetric multidimensional scaling analysis (NMDS) will be used. My goal will be to generate a plot of points (each sampled stations) where the dissimilarity values between all samples is spatially arranged into a plot. Temporal variables, including month (January-March and May-July) and year (2009-2019) will be included in the analysis and color-shape coded according to whether stations were sampled during specific months and years.

To further examine seasonal and interannual variability in larval rockfish assemblage an indicator species analysis will be used. Species abundances and occurrences will be used to determine which species serve as significant indicators for each month and year.

Cross-shelf Structure- The cross-shelf distribution of larval rockfish will be analyzed by looking at their association with changes in water masses across upwelling fronts. Changes in water mass across the Trinidad Head Line will be determined by calculating water density using temperature and salinity values from CTD data.

Changes in Assemblage Structure- Local environmental conditions (temperature and salinity) and basin-scale climate indices (sea level, Pacific Decadal Oscillation (PDO) and El Nino-Southern Oscillation (ENSO)) will be used to analyze the effects of climate variability on influencing the larval rockfish assemblage off northern California. We envision selecting a linear mixed effects model to examine the relationship between larval rockfish abundance and climate variability.

References (0 points)-no limit

Bjorkstedt EP, Rosenfeld LK, Grantham BA, Shkedy Y, Roughgarden, J (2002). Distributions of larval rockfishes Sebastes spp. across nearshore fronts in a coastal upwelling region. *Marine Ecology Progress Series*, *242*(November), 215–228.

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Laidig TE (2010). Influence of ocean conditions on the timing of early life history events for blue rockfish (*Sebastes mystinus*) off California. Fish. Bull. 108:442–449.

Larson RJ, Lenarz WH, Ralston SR (1994). The distribution of pelagic juvenile rockfish of the genus Sebastes in the upwelling region off central California. Calif Coop Ocean Fish Investig Rep 35:175–221.

Lenarz WH, VenTresca DA, Graham WM, Schwing FB, Chavez F (1995). Explorations of El Niño events and associated biological population dynamics off central California. Calif Coop Ocean Fish Investig Rep 36:106–119.

Love MS, Yoklavich M, Thorsteinson L (2002). *The rockfishes of the northeast Pacific*. Berkeley, CA: University of California Press.

Moser HG (1996). The early stages of fishes in the California Current region. Calif Coop. Oceanic Fish. Invest. Atlas 33. 1505 pp.

Ralston S, Sakuma KM, Field JC (2013). Interannual variation in pelagic juvenile rockfish (*Sebastes* spp.) abundance-going with the flow. Fisheries Oceanography 22 (4), 288–308.

Smith PE, Richardson, SL (1977). Standard techniques for pelagic, fish egg and larva surveys. *FAO Fisheries Technical Paper*, p. 100.

Thompson AR, Hyde JR, Watson W, Chen DC, Guo LW (2016). Rockfish assemblage structure and spawning locations in southern California identified through larval sampling. *Marine Ecology Progress Series*, *547*(April), 177–192.

Thompson AR, Chen DC, Guo LW, Hyde JR, Watson W (2017). Larval abundances of rockfishes that were historically targeted by fishing increased over 16 years in association with a large marine protected area. *Royal Society Open Science*, *4*(9).

Woodson CB, McManus MA, Tyburczy JA, Barth JA, Washburn L, Caselle JE, Carr MH, Malone DP, Raimondi PT, Menge BA, Palumbi SR (2012). Coastal fronts set recruitment and connectivity patterns across multiple taxa. Limnol. Oceanogr., 57: 582–596.

Wyllie-Echevarria T (1987). Thirty-four species of California rockfishes: maturity and seasonality of reproduction. Fish Bull 85:229–250.

Timeline (10 points total)-250 word maximum

We have been conducting research cruises and sampling the Trinidad Head Line since 2006. Winter and summer samples from the years 2009 to 2019 will be included in this study to characterize the larval rockfish assemblage off northern California. Currently, winter samples from the years 2009 to 2018 have been collected and sorted for larval rockfish. Summer samples have been collected and will be sorted for larval rockfish before summer 2019. Winter 2019 samples will be collected and sorted for larval rockfish before summer 2019.

Genetic sequencing will be conducted summer 2019 at the Southwest Fisheries Science Center in La Jolla, California. Genetic identification of larval rockfish should take two months to complete and is expected to be completed at the end of summer 2019. Analysis and thesis writing will begin fall 2019 and I hope to defend my thesis spring 2020.

Relation to COAST Goals (15 points total)-300 word maximum

This study enhances our knowledge of marine resources as rockfish make up an important component of the commercial and recreational fisheries off California, as well as serve as an important food source for higher trophic levels in the marine ecosystem. Severe declines in abundance of important rockfish stocks have been associated with overfishing and unfavorable environmental conditions linked to climate variability. The inability to accurately identify the early life history stages of rockfish has limited our ability to truly evaluate rockfish populations trends and dynamics off northern California. Examining seasonality of rockfish parturition and how the assemblage has changed over time in the context of climate variability, will provide useful information for fisheries managers.

This study is also consistent with COAST goals of developing solutions to the economic and ecological challenges that coastal California faces. Rockfish provide economic benefits to coastal communities in California and contributing knowledge to better understand rockfish dynamics and developing solutions to better manage rockfish stocks can greatly benefit California. Monitoring adult stocks and determining the cause of fluctuations proves a challenge for managers. Focusing on the larval stage of rockfishes can provide a useful method of studying adult stocks by investigating recruitment patterns of early life history stages, how they're affected by varying environmental conditions, and how their abundance has changed over time.

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
Taq DNA Polymerase (20 μL)	$55.00	1	-	$55.00
PCR Strip Tubes (250 tubes per box)	$255.00	5	-	$1,275.00
ExoSAP-IT (1.1 ml)	$440.00	1	-	$440.00
BigDye Terminator v3.1 Cycle Sequencing Kit	$1,230.00	1	-	$1,230.00
		Subtotal:	-	$3,000.00
		Grand Total	**$3,000.00**	

Justification (250-word maximum):

This study is dependent on the ability to identify larval rockfish to the species level. Identification of larval rockfish by genetic sequencing can run a minimum of $5 per fish, not including labor costs to run the sequencing. The cost to run 2,000 larval rockfish would cost a minimum of $10,000 and would provide a solid sample size to characterize the larval rockfish assemblage off northern California. Genetic sequencing will take place at the Southwest Fisheries Science Center in La Jolla, California.

Funds from this award would cover some of the cost of materials to conduct the genetic sequencing. Five boxes of PCR tubes, 1.1 ml of ExoSAP-IT (cleans amplified PCR product), 20 μL of *Taq* DNA polymerase, and a BigDye Terminator Cycle Sequencing kit would cover the cost of adding 500 larval rockfish to this study. Without this award, my sample size and study period (2009-2019) may be reduced and assessing year to year and seasonal variability in larval rockfish abundance and distributions may be limited to a shorter time period. These funds will allow for a substantially more robust analysis while avoiding pressure to cut into other elements of student support presently available.

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