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

Dr. Kenneth H. Coale Graduate Scholar Awards
AY 2022-2023 Application Form
Application Deadline: Wednesday, January 25, 2023, 5:00 p.m. PST

Please see information on Dr. Kenneth H. Coale Graduate Scholar Awards on the COAST **website** and read the **Announcement** for full details and instructions.

Submit this form (which includes the Advisor Sign-Off Form) 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 graduate@share.calstate.edu. **Please note**: A signature is required from your advisor on the **Advisor Sign-Off Form** only in the PDF version of your application that you submit. Your Advisor must submit your LOR to gradletter@share.calstate.edu separately.

Student Applicant Information

First Name:	Erica	Last Name:	Mills
CSU Campus:	San Diego State University	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:	Rebecca	Last Name:	Lewison
CSU Campus:	San Diego State University	Department:	Biology
Email:		Phone:	

Research Project Title:	Identifying environmental factors limiting productivity in California least terns
Project Keywords (5-7 keywords related to your project):	Sterna antillarum browni, foraging, nesting, reproductive success, climate change

Budget Summary (must add up to $4,000)

Award amount directly to awardee (through financial aid):	$4000

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):	

Committee Members (Required)

Name	Department	Campus

CSU Suggested Reviewers (Required): Suggested reviewers must be from the CSU. 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

The California least tern (hereafter "CLTE") is a federally endangered piscivorous seabird that breeds and nests April through August on beaches between central California and Baja Mexico. This species has experienced a steady population decline over the past 15 years due to low reproductive success, despite widespread implementation of site management interventions. This trend suggests that population recovery and recruitment could be limited by other factors such as changes in ocean conditions which influence fish distributions, abundance and availability. My research uses archived and contemporary biological data to explore the influence of ocean conditions on CLTE reproductive output and nest attendance.

There is increasing evidence that climate change has impacted the intensity, timing, duration, and spatial extent of ocean variability in the California Current System where CLTE breed and forage during the nesting period (Bakun et al. 2015; Wang et al. 2015). Changes in oceanographic conditions, such as upwelling strength and sea surface temperature, exert bottom-up effects on primary productivity, which impact the recruitment and distribution of mid-trophic level planktivorous fish, a primary food source for seabirds (Bakun et al. 2015). For CLTE and other coastal seabirds, there is a growing body of literature that links these oceanographic conditions to changes in population dynamics (Golet et al. 2000; Sydeman et al. 2015; Robinette et al. 2020). Recent studies suggest that a significant amount of variation in some seabird recruitment and population abundance may be mediated by prey availability (Thompson et al. 2012; Sydeman et al. 2015; Ainley et al. 2018). This ocean variability can also influence nest attendance and provisioning frequency for chicks, which can indirectly influence reproductive success. Many species of coastal seabirds are central-place foragers who travel to and from feeding areas within a limited distance from the nesting colony during the breeding season. When the availability of high-quality prey species shifts because of altered ocean conditions, adults are forced to fly further from the colony to forage or settle for less nutrient-rich prey species, decreasing energy net gain for them and the chicks they are provisioning (Warzybok et al. 2018). These changes in foraging behavior can have direct negative consequences on chick survival and overall reproductive success of seabirds, as has been observed in pigeon guillemots (Golet et al. 2000) and Caspian terns (Anderson et al. 2007).

To identify the key factors limiting California least tern reproductive success, my proposed research will leverage new and archived empirical data to explore the relationships among ocean conditions, CLTE diet, nest attendance and reproductive output. I will structure my thesis around the following hypothesis: Variation in ocean conditions over the past 20 years is linked to reproductive CLTE success as a result of changes in diet which influence nest attendance and chick provisioning. To test this hypothesis, I will collect and compile oceanographic, nest attendance/chick provisioning, and reproductive data from three major 'index' nesting sites within San Diego County: Marine Corps Base Camp Pendleton (MCBCP), Batiquitos Lagoon Ecological Reserve (BAT), and Naval Base Coronado (NBC). Each of these sites has had consistent, frequent nesting beach sampling following a standardized protocol since monitoring began in the 1970's, and together represent nearly 50% of the entire CLTE population.

My study will focus on two key metrics of oceanographic conditions, upwelling and sea surface temperature anomaly, from publicly available data collected by the National Oceanic and Atmospheric Administration (NOAA) Environmental Research Division over the past 20 years (2003-2022) (Figure 1). These data will include measurements of coastal upwelling (Coastal Upwelling Transport Index, CUTI) and vertical nitrate flux (Biologically Effective Upwelling Transport Index, BEUTI) metrics that assimilate available data from satellites and in situ platforms (Jacox et al. 2018). Sea surface temperature (SST) anomaly data will be derived from Farchadi et al. 2022, which uses NOAA's Optimum Interpolation Sea Surface temperature (OISST) database compared to a 30-year monthly climatological baseline.

To accurately characterize long-term changes in CLTE diet, I plan to measure nitrogen and carbon stable isotopes in the membranes of salvaged eggs collected between 2003 and 2023 from MCBCP and NBC. Stable isotope analysis uses mass spectrometry to identify diet patterns which can be determined from the ratios of different forms of nitrogen and carbon (e.g. 15N/14N and 13C/12C). For nitrogen, higher ratios of 15N/14N (denoted as δ15N) indicate CLTE are foraging on prey species at higher trophic levels (Kelly 2000). The measured ratio of 13C/12C, also represented as δ13C, can provide information on distance from

shore where foraging occurred, with more depleted δ13C values indicating more pelagic foraging areas (Cherel & Hobson 2007). I will pair archived stable isotope data from 330 CLTE eggs salvaged from Marine Corps Base Camp Pendleton (MCBCP) and Naval Base Coronado (NBC) between 2003 and 2012 from Fournier 2016 with new data from eggs collected between 2013 and 2023 from those same sites to evaluate changes in stable isotope ratios for both nitrogen and carbon within the diet of pre-laying females over 20 years, with each year and site represented by 10 salvaged eggs (Scientific Collecting Permit TE-213726). Previous analyses have already determined that isotopic data from salvaged versus unsalvaged eggs is not significantly different (Fournier 2016).

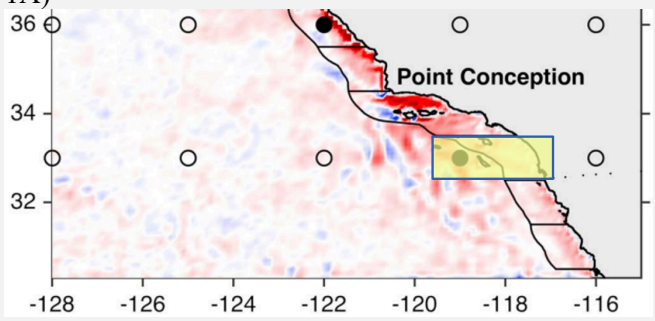
In each egg, I will isolate the eggshell membrane which forms near the end of egg production and remains metabolically inert after formation (Oppel, Powell, & O'Brien 2009; Quillfeldt et al. 2009); hence egg membrane should reflect the types of prey being foraged during the pre-laying period. To extract membranes, CLTE eggs from MCBCP and NBC are emptied of contents (yolk, albumen, embryo, etc.) and soaked in acetic acid to dissolve the calcium carbonate shell while preserving the membranes and without altering their chemical composition (Torres-Mansilla and Delgado-Mejía 2017; Shi et al. 2021). After rubbing and rinsing membrane pieces to remove acid and remaining shell material, they are dried, cut into small pieces, and loaded into tin capsules to be analyzed using an elemental combustion analyzer interfaced to a continuous flow isotope ratio mass spectrometer at San Diego State University's Ecology Analytical Lab. I will use MixSIAR to create Bayesian-based mixing models to compute the most statistically probable prey sources and their relative diet contributions by comparing eggshell membrane isotopic signatures to those of known CLTE prey species.

To measure interannual variability in nest attendance and provisioning frequency, I will use a combination of archived and newly collected nest camera data. Point Blue Conservation Science staff monitored nest attendance and provisioning frequency using remote cameras at 5 sites, including MCBCP and BAT, during the breeding seasons from 2015 and 2020. Cameras were placed at active nests and programmed to take one photo every minute from sunrise to sunset. The team reviewed footage and calculated proportions of photos in which incubation and/or chick provisioning events were observed. To supplement this data and familiarize myself with its structure, I set up my own cameras using the same protocol to monitor a total of seven nests at BAT during the 2022 breeding season, and plan to repeat this process in April - August of 2023.

Lastly, to quantify CLTE reproductive output, I will compile data from standardized metrics used in California Department of Fish and Wildlife's yearly reports, such as the ratio of minimum estimated fledglings to maximum estimated breeding pairs (hereafter 'fledge/pair ratio') and hatch success, calculated as the number of hatched eggs divided by total number of eggs. Predation or other disturbance data are not collected uniformly across index sites. However, there are some survey data available on whether observed mortalities are attributed to predation. Wherever possible, I will consider how predation and non-predation mortality rates changed over the study time period for eggs, chicks, fledglings, and adults.

With the aforementioned datasets, I plan to use structural equation modeling (SEM) to assess the strength of direct and indirect relationships between oceanographic, diet and nest attendance and CLTE reproductive output . Structural equation modeling (SEM) is a combination of a factor analysis and path analysis and can be a powerful approach for systems in which there are complex, multidimensional relationships, as it takes into account interaction effects and covariance between factors as well as the weight of the influence that each factor has on outcome variables. This approach will allow me to create multiple models and test competing hypotheses to identify which variables are directly or indirectly influencing reproductive success and to what degree.

1A)



1B)

Figure 1A: Oceanic conditions will be based on NOAA data collected in the highlighted area, centered around 33ºN and -119ºW (represented by black circle). Figure 1B: Map of three index nesting sites in San Diego County.

References (0 points): no limit

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Timeline (10 points total): 250-word maximum; any text over this limit will be redacted

From May through July I will be collecting nest attendance and provisioning data for the 2023 breeding season using remote cameras provided by the California Department of Fish and Wildlife. I have identified and am permitted to receive all necessary salvaged egg samples. Stable isotope analysis will begin once all eggshell membranes have been isolated, prepared and weighed into capsules, which may take a period of several months but will ideally be performed during the summer of 2023. Oceanographic data and CLTE reproductive data is currently being compiled, which does not require any funding. I will be working on data analysis and writing my thesis throughout the Fall of 2023 and Spring of 2024 while also taking coursework to fulfill my credit requirements for SDSU's MS degree program.

Need for Research (7 points total): 250-word maximum; any text over this limit will be redacted

The federally endangered California least tern has been experiencing a steady population decline attributed to low reproductive success since 2009, despite management interventions such as fence building, predator control, and habitat restoration. This suggests that population recovery and recruitment could be limited by climate-related shifts in ocean conditions. The proposed research will advance climate-focused research by leveraging contemporary and archived empirical data to identify the key drivers of CLTE reproductive output. Findings will inform future management decisions and funding allocation to most effectively promote successful CLTE population recovery. Furthermore, this study will serve to support research on other federally endangered or threatened species, including interior least tern (*Sternula antillarum*) and snowy plover (*Charadrius melodus; western subspp Charadrius nivosus nivosus*) which may also be experiencing similar climate-related population impacts. The framework and approach of this study will serve as a template of analysis for other seabirds of conservation concern.

Relevance to state of California (3 points total): 100-word maximum; any text over this limit will be redacted

CLTE population recovery is an ongoing priority for California wildlife agencies and considerable resources have gone toward CLTE management efforts. However, despite decades of data collection, significant gaps remain in our understanding of the factors that govern CLTE demographic change. To effectively manage, conserve, and recover populations, there is a clear need to better characterize how reproductive success is influenced by nest attendance, provisioning, predator/human disturbance, and ocean dynamics. This project directly addresses conservation priorities identified by the CLTE Technical Advisory Group in November 2022 and provides quantitative analyses that are critically needed for their conservation, recovery, and de-listing.

Budget and Justification (15 points total)

Example Budget (to use this format, erase the content below and add additional rows as necessary; alternatively, you are welcome to create your own table):

Item/Description	Unit Price	Quantity	Amount to Awardee (via Financial Aid)	Amount to Department
Stable isotope analysis lab fee	$5/sample	340	$1700.00	-
Tin capsules for solid samples 4x6mm (250 units)	$48.05	1	$48.05	-
Acetic acid (1 gallon)	$59.53	1	$59.53	-
Tuition (partial)	-	-	$2192.42	-
		Subtotals:	$4000.00	-
		Grand Total	$4000.00	

Justification (250-word maximum; any text over this limit will be redacted):

I will be performing stable isotope analysis at the Ecology Analytical Lab which charges $5 per sample to cover costs of helium used for elemental combustion, an essential step in isolating carbon and nitrogen from organic materials like eggshell membranes. Tin capsules are necessary as a combustion catalyst and to prevent cross-sample contamination. Acetic acid will be used to dissolve calcium carbonate in the eggshell, leaving only the membrane for analysis. The remaining budget will be used to defray costs of SDSU tuition which is $3300 per semester.

Application Deadline: Wednesday, January 25, 2023, 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 (with other required forms) to graduate@share.calstate.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.

AY 2022-2023 Advisor Sign-Off Form

To encourage you to engage with your CSU Advisor as you develop your application, **we are now requiring this form for <u>all</u> applications submitted to the Dr. Kenneth H. Coale Graduate Scholar Awards Program**. By signing this form, your advisor indicates that they have reviewed your application, provided guidance and input, and approved it for submission. All information except signatures must be typed. Electronic signatures are acceptable. **Please note:** A signature is required from your advisor on this **Advisor Sign-Off Form** in the **PDF version** of your application that you submit (the word document does NOT need to be submitted with a signature)

Please note: this form is NOT a substitute for a letter of recommendation (LOR). Your Advisor must submit your LOR to gradletter@share.calstate.edu separately.

Applicant Name:

Erica Mills

CSU Advisor Information:

Name:	Rebecca Lewison	Phone:	619-203-3552
Department:	Biology	Email:	rlewison@sdsu.edu

I have reviewed my student's application and provided guidance and input. My signature below indicates my approval of the application.

1/20/23

CSU Advisor Signature: _____ Date: _____