CSU 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:	Jacqueline	Department or Degree Program:	Marine Science
Last Name:	Chisholm	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:	CSUMB, MLML	Anticipated graduation date (mm/yy):	
Email:		Degree Sought (e.g., MS, PhD):	MS
Phone:		Thesis-based? (Y/N):	Y

Advisor Information

First Name:	Tom	Position/Title:	Assistant Professor
Last Name:	Connolly	Email:	
CSU Campus:	SJSU, MLML	Phone:	
Department:	Marine Science		

Research Project Title: Quantifying Discharge of Nutrient-Containing Groundwater into Moro Cojo Slough

Project Keywords (5-7 keywords related to your project): Groundwater discharge, tile drain, nonpoint source pollutant, water table

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

Award amount directly to awardee:	$3,000
Award amount to Department:	$0.00

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:		

Intentional page break – please do not delete

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

Increased anthropogenic activities have altered the health of coastal ecosystems in recent decades[1,2], resulting in eutrophication and hypoxia[3,4]. Eutrophication can decrease oxygen content throughout the water column, creating hypoxic conditions that negatively impact key species in estuarine environments[5,6]. To improve the health of estuarine ecosystems, it is essential to identify all major sources of nutrient inputs. While previous studies have identified a number of biological and physical factors influencing nutrient concentrations in estuaries[7-9], more work is necessary to assess nutrient contribution from agricultural sources.

Moro Cojo Slough is a tidally influenced estuary that discharges through the Moss Landing harbor into Monterey Bay, a Marine Protected Area (MPA), along the Central California Coast. This region is characteristic of salt marshes and low-lying wetlands. However, the historical hydrodynamics of the region have been altered significantly[10]. The mouth of Moro Cojo Slough is restricted by tide gates, limiting ocean water from entering the slough. During winter, Moro Cojo receives freshwater from precipitation and surface run-off. During the summer, the estuary receives most of its surface water from irrigation drains upstream[4,7]. The seasonal variability and tidally restricted dynamics of Moro Cojo Slough present a challenge to managing water quality for environmental standards. To better manage Moro Cojo Slough water quality, it is necessary to understand nutrient dynamics and sources within the estuary.

Estuaries in agriculturally-dominated watersheds are particularly at risk of water quality degradation. Fertilizer and irrigation run-off lead to elevated nutrient content in the main channel[10]. To reduce nutrient concentrations in irrigation drains, farmers have implemented best-practice managements that decrease irrigation water and fertilizer application. Despite efforts to reduce input, estuary surface-water nutrient concentrations remain high[12]. This suggests that a substantial portion of nutrient input may be groundwater-sourced via irrigation drains, rather than run-off-sourced. In coastal regions, shallow groundwater can flood low-lying fields and interfere with farm practices. To prevent flooding, saturated fields are dried by subsurface irrigation drains, called tile drains. Tile drains remove moisture by discharging both groundwater and irrigation water into irrigation ditches. Shallow groundwater and irrigation water mixing in tile drains has been observed, but nutrient concentrations have not been quantified during this mixing process[13].

In comparison to surface water, groundwater often contains higher concentrations of chemical constituents, including nutrients (NO_3^-, NH_4^+, PO_4)[3]. High nutrient concentrations in groundwater are a result of historical anthropogenic activities and microbial degradation processes. While groundwater discharge may contribute a low volume to surface waters, groundwater content greatly influences surface-water quality[14,15]. Recent water quality monitoring efforts indicate that groundwater discharge may enter surface waters through upstream irrigation drain systems within agriculturally-dominated estuarine watersheds. **Nutrient budgets have yet to incorporate the contribution of groundwater nutrients in tile drains to the high nutrient concentrations found in agriculturally-dominated estuaries. Further research is necessary to understand groundwater mixing in irrigation systems and its relative contribution to the estuary main channel.**

Research Objectives

The overall objective of this is to determine the relative contribution of nutrient-containing groundwater discharge to Moro Cojo Slough via agricultural drainage systems. Specifically, I will address the following research questions and hypotheses:

Question 1: What is the relative contribution of nutrient loading to Moro Cojo Slough from shallow groundwater in agricultural drainage systems?
Hypothesis 1: Shallow groundwater in Moro Cojo watershed will contribute to high nutrient concentrations in tile drain systems discharging to surface waters. Nutrient loading will be assessed using nitrate, nitrite, phosphate, and ammonium concentrations in water samples and discharge rates of tile drain and irrigation water. Radon-222 (radon) will be used as a tracer for groundwater discharge to tile drains and surface waters. Elevated amounts of radon will indicate increased groundwater input to surface waters, which will be modeled using radon flux calculations[16]. Nutrient sources (e.g., groundwater, fertilizer, microbial processes) in tile drains and the main channel will be identified using nitrate isotopes. This will demonstrate if groundwater is a source of nutrients to agricultural estuaries.

Question 2: Is there seasonal variability of groundwater contributions to tile drain mixing and to Moro Cojo Slough?
Hypothesis 2: Groundwater contribution to tile drains and the main channel will be greatest during seasons of high precipitation. Nutrient concentrations and groundwater discharge will be measured throughout the year to account for seasonal and crop-rotation variability. Groundwater, tile drain water, and surface water will be sampled during dry and wet seasons as well as during all stages of crop production. During the wet season, samples will be taken before and immediately after rain events. In situ monitoring of radon will take place in main-channel surface waters, while radon grab samples will be taken of groundwater and tile drain water in irrigation ditches. Nitrate isotope samples will aid in determining the source of all water samples taken.

Question 3: What significant nutrient sources contribute to the main channel of an agriculturally-dominated estuary via irrigation drain systems?
Hypothesis 3: Groundwater will significantly contribute to the main-channel surface water nutrient budget. Nitrate isotopes will be evaluated for groundwater, tile drain water, and surface water samples. Isotopes signatures will provide insight to nutrient sources within irrigation drain system. Building upon previous working models, a nutrient budget for Moro Cojo Slough will quantify the relative contribution of groundwater from tile drains to the overall water quality of the main channel[11]. The budget will incorporate sources and sinks of nutrients in the Moro Cojo Slough.

Experimental Design & Methods

Sampling

I will sample 8 tile drain sites in the Moro Cojo watershed over a two year period to document seasonal and temporal variability in ground water discharge. Samples will be collected throughout the year with a goal of obtaining samples during both the wet and dry seasons and at different stages of local agriculture growing cycles (pre- and post-planting, irrigation, fertilization, and harvesting). At each site I will collect surface water, irrigation water, and groundwater grab samples in Nalgene HDPE bottles and Falcon centrifuge tubes. Groundwater will be collected using a drive-point piezometer and a peristaltic pump. A tube will allow water to flow from the piezometer to the bottles without the groundwater interacting with the atmosphere.

Water quality parameters, sediment characteristics, and nutrients will be measured in each sample. Water quality parameters will be recorded using a handheld YSI multiparameter meter. Sediment characteristics will be assessed for porosity, grain size, and hydraulic conductivity to aid in assessment of groundwater discharge in the region. Nutrient concentration, radon, and nitrate isotope fractionation will be used to calculate groundwater discharge[13,16].

Laboratory Analysis

Nutrient Loading – Nutrient concentration and discharge flow rates will be used to quantify nutrient loading along the estuary channel and within irrigation drain systems. Grab samples will be taken for tile drain water, groundwater, irrigation water, and surface water. Each sample will be analyzed for nitrate, nitrite, phosphate, ammonium using a Lachat Flow Injection Analysis instrument at Moss Landing Marine Laboratories. Flow of irrigation drains, tile drain water, and main-channel surface water will be assessed using an OTT MF PRO® flow meter. Flow measurements will follow the USGS monitoring protocol[17].

Radon-222 Activity – Radon-222 (radon) is naturally elevated in subsurface water and will be used as a tracer for groundwater. High radon activity will indicate groundwater discharge influence in irrigation water and surface water. Grab samples will be filled in a HDPE 6L Nalgene bottle from the bottom, as to prevent sample aeration[18,19]. Radon in grab samples and in main-channel surface waters will be analyzed using a Durridge RAD7 radon detector. Groundwater discharge and mixing will be calculated using a well-established continuous radon inventory model, accounting for temperature, volume, and gas evasion[19,20].

Nitrate Isotopes – Nitrate (NO_3^-) isotopes ($\delta^{15}N$ and $\delta^{18}O$) will provide insight to nitrogen cycling within the Moro Cojo watershed[21]. Isotope fractionation values will be used to determine nitrate sources for groundwater, tile drain water, irrigation water, and surface water within irrigation drains. Biogeochemical processes, such as nitrification and denitrification, result in nitrate isotope signatures characteristic to the nitrate source. These sources include nitrate in fertilizer, soil, and precipitation. Sources of nitrate will demonstrate the transport of nutrients throughout the Moro Cojo watershed, allowing groundwater as a pollutant source to be identified. Water samples will be analyzed using the denitrifier method at the stable isotope facility at University of California, Davis[22,23].

Statistical Analysis

Variation in groundwater, irrigation water, tile drain water, and surface water samples will be analyzed using Kruskal-Wallis nonparametric one-way analysis of variance. Linear regression will determine correlation between sample and season using 95% confidence interval[15]. Isotope data will be assessed using a Bayesian mixing model and multivariate statistical analysis[24].

Modelling

Using these data, I will model groundwater discharge to in tile drain systems to Moro Cojo Slough surface waters, improving upon a previous model of the estuary[11]. Sources of water will include net precipitation and evaporation, freshwater discharge, sediment-water exchange (i.e., groundwater discharge), surface run-off, tidal flow, and irrigation ditch input. Nutrient sources and sinks will include atmospheric deposition, surface run-off, sediment-water exchange (i.e., benthic respiration or groundwater discharge), nutrient uptake within the water column (i.e., primary productivity), tidal exchanges, freshwater discharge and irrigation drain discharge.

References (0 points)-no limit

1. Kennish, M.J., 2001. Coastal salt marsh systems in the US: a review of anthropogenic impacts. Journal of Coastal Research 17(3): 731– 748.
2. Hicks, K., 2018. 30 Years of Water Quality at the Elkhorn Slough and Surrounding Wetlands. Elkhorn Slough National Estuarine Research Reserve. Unpublished.
3. Valiela, I., Costa, J., Foreman, K., Teal, J. M., Howes, B., and Aubrey, D., 1999. Transport of groundwater-borne nutrients from watersheds and their effects on coastal waters. Biodegradation, 10(3), 177-197.
4. Kennison, R. L., Fong, P., 2014. Extreme Eutrophication in Shallow Estuaries and Lagoons of California Is Driven by a Unique Combination of Local Watershed Modifications That Trump Variability Associated with Wet and Dry Seasons. Estuaries and Coasts, 37 (Suppl 1): S164–S179.
5. Gee, A. K., Wasson, K., Shaw, S. L., 2010. Signatures of Restoration and Management Changes in the Water Quality of a Central California Estuary. Estuaries and Coasts (2010) 33:1004–1024.
6. Jeppesen, R., Rodriguez, M., Rinde, J., Haskin, J., Hughes, B., Mehner, L., Wasson, K., 2016. Effects of Hypoxia on Fish Survival and Oyster Growth in a Highly Eutrophic Estuary. Estuaries and Coasts 41(1): 89–98.
7. Caffrey, J., Harrington, N., Solem, I., Ward, B. B., 2003. Biogeochemical processes in a small California estuary. 2. Nitrification activity, community structure and role in nitrogen budgets. Marine Ecology Press Series. 248: 27–40.
8. Breier, J. A., Nidzieko, N., Monismith, S., Moore, W., Paytan, A., 2015. Tidally regulated chemical fluxes across the sediment–water interface in Elkhorn Slough, California: Evidence from a coupled geochemical and hydrodynamic approach. Limnol. Oceanogr., 54(6), 2009, 1964–1980.
9. Nidzieko, N. J., Needoba, J. A., Monismith, S. G., Johnson, K. S., 2014. Fortnightly tidal modulations affect net community production in a mesotidal estuary. Estuaries and Coasts 37 (Suppl 1): S91-S110.
10. Caffrey, J. M., Brown, M., Tyler, B., Silberstein, M., 2002. Changes in a California estuary: an ecosystem profile of Elkhorn Slough. Moss Landing: Elkhorn Slough Foundation. Text, p. 280.
11. Wise, M., Coale, K., Graham, M., Null, K., 2017. Nutrient dynamics in a tidally restricted region of the Elkhorn Slough National Estuarine Research Reserve. Moss Landing Marine Laboratories. Unpublished.
12. INM Final Report, 2017. Salinas INM Prop 84 Monitoring Report for Oceanmist Bioreactor, PG&E Treatment Wetland, and Azevedo Bioreactor.
13. Webb, J. R., Santos, I. R., Robson, B., Macdonald, B., Jeffrey, L., Maher, D. T., 2017. Constraining the annual groundwater contribution to the water balance of an agricultural floodplain using radon: The importance of floods. Water Resources Research, 53(1), pp.544-562.
14. Burnett, W. C., Aggarwal, P. K., Aureli, A., Bokuniewicz, H., Cable, J. E., Charette, M. A., Kontar, E., Krupa, S., Kulkarni, K. M., Loveless, et al., 2006. Quantifying submarine groundwater discharge in the coastal zone via multiple methods. Science of the Total Environment 367 498–543.
15. Null, K. A., Knee, K. L., 2011. Submarine groundwater discharge-derived nutrient loads to San Francisco Bay: Implications to Future Ecosystem Changes. Estuarine, Coastal and Shelf Science, 95(2), pp.314-325.

16. Burnett, W. C., Dulaiova, H., 2003. Estimating the dynamics of groundwater input into the coastal zone via continuous Radon-222 measurements. Journal of environmental radioactivity, 69(1), pp.21-35.
17. Buchanan, T. J., Somers, W. P., 1976. Discharge Measurements at Gaging Stations. Techniques of Water-Resources Investigations. United States Geological Survey, Book 3, Chap. A8, p. 65.
18. Burnett, W. C., Kim, G., Lane-Smit, D., 2001. A continuous monitor for assessment of 222Rn in the coastal ocean. Journal of Radioanalytical and Nuclear Chemistry, 249 (1), 167–172
19. Simone, G. D., Galli, G., Lucchetti, C, Tuccimei, P., 2015. Calibration of Big Bottle RAD H_2O set-up for radon in water using HDPE bottles. Radiation Measurements 76, 1-7
20. Lambert, M. J., Burnett, W. C., 2003. Submarine groundwater discharge estimates at a Florida coastal site based on continuous radon measurements. Biogeochemistry 66: 55–73
21. Wankel, S. D., Kendall, C., Paytan, A., 2009. Using nitrate dual isotopic composition (d15N and d18O) as a tool for exploring sources and cycling of nitrate in an estuarine system: Elkhorn Slough, California. Journal of Geophysical Research. 114, G01011
22. Sigman, D. M., Casciotti, K. L., Andreani, M., Barford, C., Galanter, M., Bohlke, J. K., 2001. A bacterial method for the nitrogen isotopic analysis of nitrate in seawater and freshwater. Analytical Chemistry, 73, 4115-4253
23. Granger, J., Sigman, D. M., 2009. Removal of nitrite with sulfamic acid for nitrate N and O isotope analysis with the denitrifier method. Rapid Communications in Mass Spectrometry, 23, 3753-3762.
24. Matiatos, I., 2016. Nitrate source identification in groundwater of multiple land-use areas by combining isotopes and multivariate statistical analysis: A case study of Asopos basin (Central Greece). Science of the Total Environment. 541, 802-814.

Timeline (10 points total)-250 word maximum

This project began during Summer 2018. In collaboration with the Central Coast Wetlands Group, I have established connections with local farmers to sample various irrigation drains and agricultural fields. I have collected water samples (i.e., groundwater, tile drain water, irrigation water, and surface water) at 8 tile drain sites and 2 main channel sites. All samples were analyzed for nutrients (i.e., phosphate, nitrite, nitrate, and ammonium), Radon-222 activity, and nitrate isotopes. These data are currently being processed and guiding decisions for how to proceed during the second year of sample collection. The first year of sample collection concluded January 2019. The second year of data collection will start February 2019 and conclude in January 2020. Due to a delay in the distribution of Sea Grant funds this past year, an additional data collection period will take place from January 2020 to June 2020. Given this collection timeline, I expect to complete and defend my thesis during Fall 2020. Additionally, data dissemination will occur in the form of poster presentations at conferences (i.e., Geological Society of America, American Geophysical Union, Association for the Science of Limnology and Oceanography) throughout 2019-2020. The results of my project will be submitted to be published following completion of my degree in 2021.

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

In alignment with all of COAST's goals, my project promotes exploring the impacts of a previously unstudied nonpoint source pollutant impacting water resources. It develops a solution for ecological limitations in groundwater sample collection. Finally, it fosters scientific literacy through partnership with farmers, environmental groups, and policymakers.

While watershed monitoring stations have observed water quality in Central California throughout the past few decades, there is a lack of understanding regarding the role of groundwater within this watershed. This study will provide valuable data and knowledge to understand groundwater-surface water interactions and the impact on nutrient loads. The study has the potential to identify a major component of nonpoint source pollution not previously considered in many agriculturally-dominated estuaries or other coastal water resources.

Groundwater monitoring can be limited by accessibility of sample water. As a result, water quality efforts around Central California have yet to incorporate groundwater quality as a component to monitoring programs. My study will develop a sampling protocol that will be adaptable and made available for water monitoring efforts across the region. Our sampling approach will develop a feasible solution for sampling shallow groundwater and will make groundwater studies more accessible for the future.

If groundwater supplies a majority of the nutrients to surface waters, then no matter the effort of on-farm management practices, nutrients will not be reduced in surface waters. Therefore, off-farm mitigation (wetlands and bioreactors) strategies would need to be installed. In partnership with the Central Coast Wetlands Group and local farming leaders, my sampling framework and other mitigation strategies will be incorporated into current watershed monitoring strategies along the California Coast, including Moro Cojo. My project will provide data and new knowledge that will be directly communicated to farmers, policymakers, and environmental groups to update agricultural orders and management efforts that address nutrient loading.

Budget and Justification (15 points total)

Item/Description	**Unit Price**	**Quantity**	**Amount to Awardee (via Financial Aid)**	**Amount to Department**
Tuition	-	-	$3000.00	-
		Subtotals:	*$3000.00*	*$0.00*
		Grand Total	**$3,000.00**	

Justification (250-word maximum):

If granted the opportunity to be a COAST Graduate Student Research Award recipient, I would use my award to fund my tuition. Thus far, I have relied upon federal student financial aid to support my pursuit of higher education, including both my undergraduate and graduate school programs. Throughout my education, it has been necessary for me to work while balancing my academic career. While the high price of education can be burdensome, the experiences I am gaining while at Moss Landing Marine Laboratories are priceless. Receiving this research grant will allow for me to focus my time on my research project, to expand my knowledge through coursework, and to increase my community involvement as a volunteer. The opportunity to fund my tuition will help me to advance my skills as a marine scientist as well as to readily participate in my community through educational volunteering and outreach at Elkhorn Slough National Estuarine Research Reserve.

Thank you for your time and consideration of my application.

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.