# University of Southern California Sea Grant Proposal

Submitted by Cal Poly State University, San Luis Obispo

## 1. PROJECT TITLE:

RECOVERY OF THE PISMO CLAM (*TIVELA STULTORUM*) IN CALIFORNIA: THE IMPORTANCE OF POLLUTION

## 2. PRINCIPAL INVESTIGATORS:

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## 3. ASSOCIATE INVESTIGATORS:

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## 4. FUNDING REQUESTED:

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|---|---|---|---|---|
| 2016-2017 | $45,755 | Request | $30,999 | Match |
| 2017-2018 | $19,245 | Request | $32,394 | Match |

## 5. STATEMENT OF THE PROBLEM:

As in much of the world, California is increasingly urbanized, with 95% of the state's population living in cities. These urban populations are also increasingly near the coast, with over 68% of Californians living in a coastal county (US Census Bureau 2010). These growing coastal and urban populations can impact coastal resources both directly (e.g. harvest) and indirectly (e.g. habitat loss, pollution). Understanding these impacts is critical to managing these coastal resources sustainably (e.g. Cooke and Cowx 2006).

Many bivalves play essential roles in coastal ecosystems, and yet often live in nearshore environments in close proximity to human populations, subject to many of the threats of urbanization (e.g. Dame 2012). One species that exemplifies this issue is the Pismo clam (*Tivela*

*stultorum*). The Pismo clam, which ranges from Monterey Bay to southern Baja California, Mexico once supported a thriving commercial and recreational fishery in California. Commercial landings averaged nearly 100 metric tons per year between 1916 and 1947 and recreational clammers harvested ~2 million clams over a 2½ month period from the Pismo Beach-Oceano area alone in 1949 (Shaw and Hassler 1989, Pattison and Lampson 2008). Since that time, abundance of Pismo clams has declined precipitously; commercial harvest was prohibited in 1948 and recreational harvest is no longer viable in many locations (Shaw and Hassler 1989, Pattison and Lampson 2008).

One factor that has likely affected the recovery of Pismo clams is the resurgence of the Southern sea otter *(Enhydra lutris nereis*) in locations from which it had previously been extirpated. In a survey of clam populations from Monterey to Newport Beach, Miller et al. (1975) found that catch per unit effort of clams dropped to near zero on beaches where sea otters had been foraging for at least a year. In Pismo Beach, the recreational catch declined from 343,000 clams in 1978 prior to otters to 0 in 1983 after otters moved into the area (Wendell et al. 1986). Abundance increased slightly during the early 1990s but these populations remain small today (Pattison and Lampson 2008), and transplant efforts to increase abundance have generally failed (Shaw and Hassler 1989). While otters may be impacting Pismo clam recovery north of Point Conception (the southern extent of the otters current range), our preliminary data show that abundance in Southern California is also low (Fig. 1). Therefore, it is clear that factors other than otters are limiting Pismo clam abundance in Southern California.

One potential factor that may be affecting the recovery of Pismo clams in Southern California is pollution. Water pollution can have negative impacts on the survival and physiological processes of both adult and larval stages of many aquatic species (e.g. Dinnel et al. 1989, Key et al. 1998).

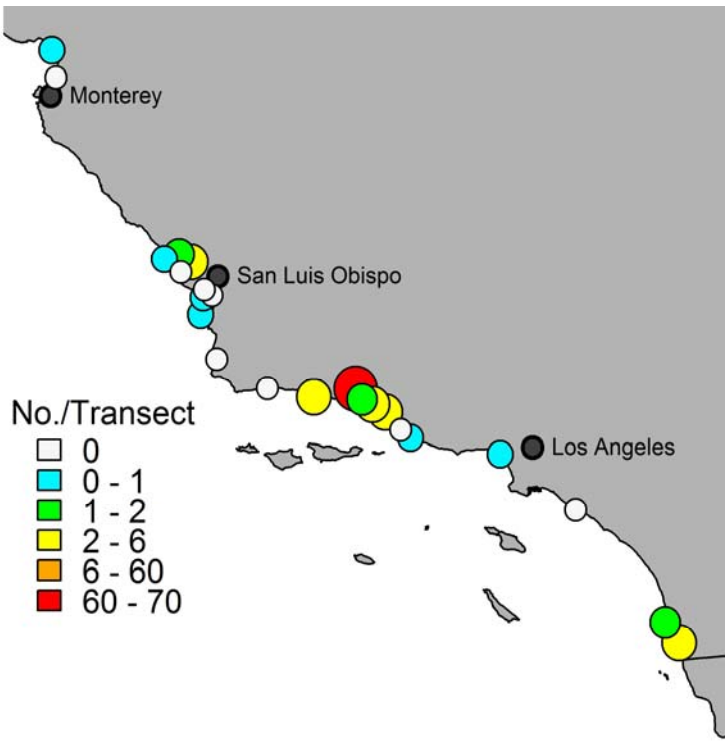


Figure 1. Density of Pismo clams in the intertidal of sandy beaches in California from Jan 2014-Mar 2015. Note that Rincon, the large red dot, had a density of more than 10 times any other site, and that Coal Oil Point is the closest site to Refugio State Beach where clams were found (yellow circle west of Rincon). Both Coal Oil Point and Rincon were surveyed in June 2015, after the Refugio Oil Spill; densities at both of these locations had declined by around six-fold but we cannot conclusively state that the spill caused these declines.

In addition, early life stages of many marine invertebrates are particularly sensitive to pollutants and water quality (e.g. Beiras and His 1994, Key et al. 1998). Anthropogenic pollutants may limit recruitment of many species in Southern California, where human population densities, urbanization, and pollution is much higher (e.g. Fowler 1990, Nelson et al. 2008).

To better understand the current status of Pismo clams and the factors limiting their recovery, we must address a number of questions. First, we need information on the abundance and distribution of Pismo clams to understand the local and regional factors that may correlate with high and low abundance. The California Department of Fish and Wildlife (CDFW) has collected some data on Pismo clam populations over the last few decades, but with few resources available for this project, CDFW data are scattered spatially and temporally, reducing their utility for management. Starting in early 2014, our research team built on the CDFW surveys to generate preliminary data on the size structure and distribution of Pismo clams across their range in California (see Fig. 1) and we are initiating a citizen-science program to further increase spatial and temporal resolution of these data.

Second, we need a better understanding of the potential factors limiting Pismo clam populations. Population limitation could occur in the adult, larval, or juvenile/recruit life stages and may be driven by a number of factors such as predation (e.g. sea otters and other predators) and pollution. In addition, limiting factors may be different in different locations. For example, sea otters are thought to be important predators of adult Pismo clams along the central coast (e.g. Miller et al. 1975), but they are not found south of Point Conception/Gaviota. Conversely, human population densities, urbanization and pollution are much higher in Southern California.

Understanding both the distribution and abundance of Pismo clams as well as the factors that limit their populations will help us develop appropriate management strategies and guide restoration of this iconic but depleted species.

## 6. INVESTIGATORY QUESTION:

Our primary objectives are to evaluate the levels of toxins present in Pismo clam adults and recruits to determine the impacts of environmentally relevant levels of these toxins on survivorship of Pismo clam larvae, with an emphasis on urbanized areas in Southern California. These objectives will help us understand the impact of pollution as a limiting factor on Pismo clam populations, and they also generate a series of testable hypotheses:

*Hypothesis 1*: *clams collected from Southern California will have higher levels of toxins than those from Central California, and sites close to large urban centers (e.g. Los Angeles, San Diego) will have the highest levels of toxins*. To test this hypothesis, we will make collections of adults and recruits from several beaches in Central and Southern California. We will collect clams from sites where our preliminary abundance surveys suggest adults and/or recruits are likely to be present, and where anthropogenic pollutants are likely to vary (i.e. Central vs Southern California and more urbanized vs less urbanized locations). We will conduct standard toxicological assays on clam tissues for a variety of toxins including pesticides and herbicides, endocrine disrupters, and hydrocarbons.

*Hypothesis 2: toxin concentrations at the upper bounds of levels found during the evaluation of hypothesis 1 will result in increased developmental times, increased developmental abnormalities, and increased mortality in Pismo clam larvae compared to lower concentrations.* To evaluate this hypothesis, we will conduct a series of experiments on larvae reared in water with high and low levels of toxins that were identified in hypothesis 1. We will set upper and lower concentrations of these toxins based on values from hypothesis 1 as well as data from the literature and input from water quality professionals, and evaluate larval development and survivorship.

## 7. MOTIVATION:

Pismo clams once supported thriving commercial and recreational fisheries in California, but populations of clams have declined dramatically in recent decades (Pattison and Lampson 2008). For example, the City of Pismo Beach has a Pismo clam festival every year, despite the fact that no legal-sized clams (>115 mm) have been found in the area since the mid-1990s. Our interest in this topic was sparked by conversations with City officials, who sought information about why Pismo clams have all but disappeared from the region, and what, if anything, might be done to bring them back (see letters of support). Furthermore, population declines are not limited to the central coast; Pismo clams were once abundant in Southern California, but have declined there as well (Fitch 1950, Miller et al. 1975; Fig. 1).

Therefore, our long-term research objectives are to understand the causes of the decline of Pismo clams across their range in California and to identify the factors that are inhibiting population recovery. Ultimately, we hope to use this information to develop and evaluate restoration actions. In recognition that these objectives will require many years of research both locally and across the state, we have initiated a multi-pronged research program. The first step is to document the status of populations statewide. Our initial surveys included over 23 sites in Central and Southern California. These data show that abundances are generally low statewide, even in places that have been reported to have high abundances in the past, such as south San Diego County and Orange County (Fig. 1). The one outlier in our data is Rincon Point on the Santa Barbara-Ventura County line, with densities more than 10 times greater than those of any other site. Interestingly, our preliminary statewide data do not reveal any clear spatial pattern in the abundance of Pismo clams. Furthermore, they are not correlated with any of the proposed drivers of Pismo clam abundance, such as the presence/absence of sea otters as predators, strong thermal gradients between Central and Southern California, variability in human populations, human harvest pressure, or other stressors that may vary with urbanization (e.g. habitat modification, pollution).

To increase our temporal and spatial coverage, we are expanding our survey program to include a citizen science component to this project; we have developed smartphone apps to facilitate data collection in collaboration with Cal Poly computer engineering students, and we plan to begin field testing these apps in the fall. This survey component of our research program will help provide the first comprehensive statewide assessment of the status of Pismo clams populations in many decades.

In addition, our size structure data reveal differences in size frequencies in different regions (Fig. 2). Central California populations are clumped around moderate sizes with few larger and few smaller individuals, and no legal-sized individuals. Southern California populations are more evenly distributed amongst size classes, but legal-sized individuals are still very rare. At the same time, the fact that there is a at least one location with extremely high densities of Pismo clams—Rincon—suggests that the right conditions still exist to support large populations. Furthermore, the size structure at Rincon is truncated at the legal size limit, and we have observed many recreational clammers at this site each time we have surveyed it, suggesting that this large population persists in spite of heavy human harvest pressure. Combined, these preliminary data suggest that recovery of Pismo clam populations may be limited by different factors in different parts of the state.

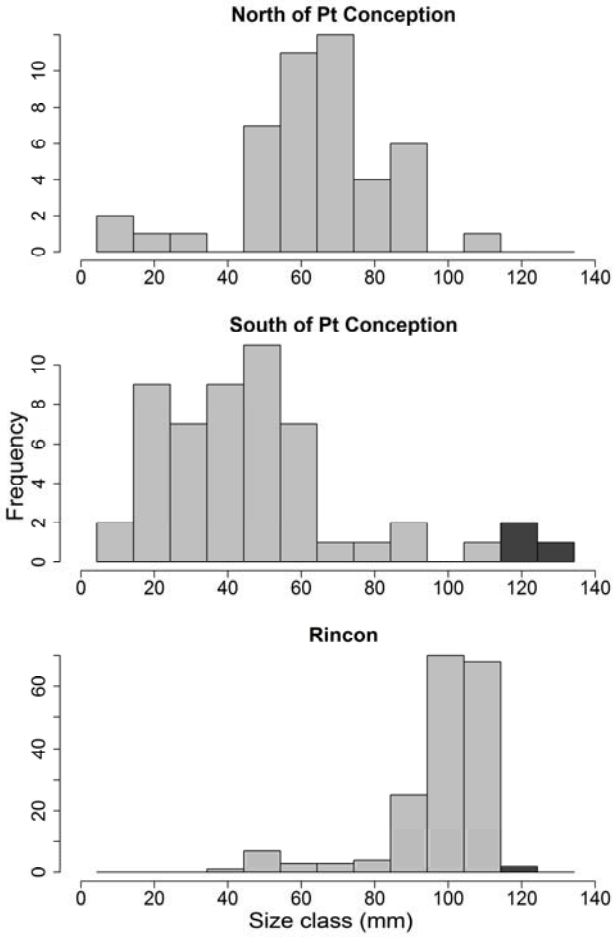


**Figure 2.** Size structure of Pismo clams. Dark gray bars above 114.3mm are legal sized clams (note: legal size is 127mm from Monterey County northwards, but no clams were found in that region). Clams found at Rincon are only included in that plot (e.g. they are excluded from the plot of South of Pt Conception). Note the small number of legal sized clams found in the study.

Previous work has suggested that sea otters and human harvest have reduced Pismo clam populations in Central California. However, human harvest is likely lower in Southern California than at the peak in Pismo Beach, and sea otters are not present in Southern California.

Pollution, on the other hand, is one factor for which we have no historical nor current data for Pismo clams. In Southern California, an extensive suite of anthropogenic pollutants have been detected in the ocean, marine sediment, and bivalve tissue, including pesticides, herbicides, endocrine disrupters, and hydrocarbons (Lauenstein and Daskalakis 1998, Nelson et al. 2008, Alvarez et al. 2014). A large body of research suggests that these contaminants can have both lethal and sublethal effects on marine organisms (e.g. Dinnel et al. 1989, Key et al. 1998), and that these impacts may be particularly detrimental to filter-feeding, sessile invertebrates found in nearshore habitats (Doddler et al. 2014). Studies have shown that many of these nonlethal effects may reduce reproductive output (e.g. Dinnel 1989, Depledge and Billinghurst 1999, Rodriguez et al. 2007) and lethal effects of toxins can be especially acute on larvae (Key et al. 1998). Together, these

impacts of pollutants may cause synergistic reductions in recruitment of affected species, with ultimate reductions in adult population sizes. As a species that lives in the low intertidal on beaches, Pismo clams may be particularly vulnerable to the impacts of anthropogenic pollutants.

The recent oil spill at Refugio State Beach near Santa Barbara highlights the potential negative effects of hydrocarbon toxins. Following the spill, there was widespread mortality on a range of marine organisms, including nearshore marine invertebrates (Refugio Response Joint Information Center and CDFW, unpublished data). We had pre-spill survey data from Coal Oil Point and Rincon Point (roughly 20 and 55 km east of the spill site, respectively). Even though these sites were far from the location where oil entered the ocean, there were reports of oil washing up on these beaches. Cal Poly researchers resurveyed these two locations approximately two weeks after the spill and found that abundance at both locations was much lower after the spill. Densities declined from 60 clams to 9 clams per transect at Rincon, and 2 clams to 0.3 clams per transect at Coal Oil Point. Bivalves will incorporate compounds released from anthropogenic oil spills into their tissues (e.g. Carls et al. 2001). While there is a paucity of before oil spill abundance data for many species, and Pismo clams in particular, the few studies examining mortality or changes in abundance have shown declines of 10 – 20% in transplanted bivalve abundance after oiling (e.g. Dow 1975, Fukuyama et al. 2000) While our data are currently insufficient to conclude that the spill caused the declines in abundance at these two sites, they are consistent with known lethal and nonlethal impacts of oil pollution on bivalves.

Our data, evaluating the levels of toxins in Pismo clams and the impacts of these toxins on the development and survivorship of larvae, will provide guidance on the relative importance of pollutants to the decline of Pismo clam populations, particularly in urban Southern California. Ultimately, we will combine this information with related data on the abundance of adult and recruit clams throughout California to guide actionable restoration activities designed to return Pismo clams to previous levels of abundance. We will provide our results to all interested state and federal resource management agencies; we have excellent working relationships with staff at CDFW, NOAA's National Marine Sanctuaries, the National Park Service, the Central Coast Regional Water Quality Control Board, and a number of local municipalities (see letters of support).

## 8. GOALS AND OBJECTIVES:

### A. Overall Goals

We have several short-term and long-term goals and objectives for this research program. Over the long term, we seek to document the current status of Pismo clam populations throughout California and understand the causes of their decline, including the impacts of predation, pollution, habitat modification, and recreational harvest. We will provide all of our data and results to the relevant state and federal management agencies—many of whom have written letters of support—and we will use our findings to make concrete suggestions to guide restoration activities of Pismo clams throughout the state.

### B. 2016-2018 Objectives

Over the next two years, we seek to understand the relative importance of pollution on adult and recruit Pismo clams and on how pollution may impede recovery of Pismo clam populations. Specifically, we have two primary objectives:

1. We will evaluate the levels of anthropogenic toxins in the tissues of adults and recruits of Pismo clams throughout California, emphasizing both urbanized areas with significant anthropogenic impacts and more remote areas with less human influence. These data will provide information on potential levels of toxins on individual clams and how toxins are distributed in space and across life stages. These data will also help us set levels for manipulative experiments using larval clams in part 2.
2. We will quantify the effects of environmentally relevant levels of toxins on Pismo clam larval development and survivorship. Much of the previous work on Pismo clams suggests that recruitment processes and recruitment failure may be key factors in limiting adult populations (Miller et al. 1975), but few of these previous studies have examined recruitment at all (but see Stephenson 1974) and none have correlated high or low recruitment events with any potential driver. These data will be the first to experimentally evaluate one of the hypothesized mechanisms (larval development and survivorship) to explain low recruitment in Pismo clams.

## 9. METHODS:

*Population surveys and toxicological assays*

The first step in this project will be to evaluate levels of toxins in the tissues of Pismo clam adults and recruits at sites throughout the state. Urban areas are likely sources of many environmental pollutants through sewage outfalls, storm and surface runoff, harbors, and river mouths. These sources can include a variety of toxins such as pesticides/herbicides, endocrine disrupters, hydrocarbons, and other industrial waste products. Therefore, we will sample locations close to and further from urban centers (high and low anthropogenic impact), since urban areas will have many of these potential sources of toxins.

While our sampling will emphasize Southern California with its large urban areas, we will include high and low anthropogenic impact sites in Central and Southern California. High impact sites in Southern California may include Imperial Beach near the mouth of the Tijuana River; Coronado near San Diego Bay; Santa Monica, Manhattan Beach/Redondo Beach, and Long Beach/Huntington Beach near Los Angeles. Low impact sites in Southern California may include Camp Pendleton/San Onofre; Malibu/Point Mugu; Carpinteria State Beach; Hollister Ranch; and potentially the Northern Channel Islands. We will also include Rincon Point, since it has the highest densities of clams we recorded, and Coal Oil Point in Santa Barbara, since it is the closest site we have surveyed to the Refugio Oil Spill, a known source of significant hydrocarbon pollution.

Since human populations are much lower in Central California, sites in central California will serve as a comparison to the urban oceans of Southern California. We will make collections near the highest population centers in Pismo Beach and Morro Bay and in more remote areas, such as Point Sal, Purisima Point, Jalama State Beach, and the Big Sur Coast. Monterey Bay is also

populated but our preliminary survey data and anecdotal evidence suggests that densities of Pismo clams are extremely low in this region.

We will conduct surveys for adult Pismo clams using the standard methodologies we have been employing (e.g. Pattison and Lampson 2008); briefly, beaches will be surveyed on low tides of at least -0.5 ft; the survey team will lay out a transect perpendicular to the shoreline around 50 cm higher in elevation from the low water mark and will dig a transect towards the waterline the width of a standard flat shovel (around 25 cm wide), recording GPS coordinates at the start and end of each transect. The length of the transect will vary depending on the slope of the beach; transects will end just past the waterline when digging becomes difficult. To survey recruits, we will shovel excavated sand into a large bin with a ~1cm mesh size screen. The bin will be shaken to remove the sand and only larger objects such as rocks, shells, and smaller Pismo clams remain (Stephenson 1974). All clams found will be counted and measured.

A subset of adult and recruit clams from each site will be collected for further analyses and experiments. We will collect ~5 adult and recruit clams for toxicological assays; these samples will be immediately placed on ice, and the soft tissue will be homogenized (Kimbrough et al. 2006). The homogenized tissue will be stored on dry ice and later transferred to a -80°C freezer at Cal Poly for storage until samples are prepared and sent for analysis. Samples will be sent to the Analytical Lab in the Institute for Integrated Research in Materials, Environments and Society at California State University Long Beach. Toxicology data will be analyzed using nested linear mixed effects models, including region (Southern vs Central) and human impact (more vs less urbanized) as fixed factors, site as a random factor, and clam size as a covariate.

We will also collect 5-10 adult clams from the higher density sites for spawning experiments, including high and low human impact sites in both Central and Southern California. These clams will be etched to permanently identify them and placed in aerated seawater for transport to the flow through seawater lab at the Cal Poly pier. We have developed a tank system that mimics wave action at this facility, and we have ~40 clams at the moment that we are using for preliminary experiments. All collections have been and will be made in non-MPA areas under our permit no. 6681, issued by the CDFW.

We will also archive a small amount of tissue in an -80°C freezer at Cal Poly a from a subset of clams for potential future proteomic analyses; these analyses provide detailed information about specific protein expression, and are therefore extremely useful in understanding physiological responses to environmental toxins. Cal Poly has an Environmental Proteomics Laboratory, but these analyses are extremely expensive and beyond the scope of this proposal. However, we will archive tissue in the event that funding for this work becomes available in the future.

*Impacts of toxins on Pismo clam larval development and survivorship*

Our second objective is to evaluate the impacts of toxins on larval development and survivorship. We will conduct experiments on Pismo clam larvae reared in water with high and low levels of key toxins; we will select toxins based on preliminary results from hypothesis 1 and as well as input from water board staff and publically available water quality monitoring data. Because maternal effects (e.g. temperature regime, adult exposure to toxins) may impact larval development and survivorship, we will include information on spawner source location as

additional factors (i.e. Central or Southern California and high or low human impact). We will set upper and lower concentrations of these toxins based on information from the literature and water quality monitoring reports, and evaluate larval development and survivorship using standard developmental assays. We will also include controls in seawater.

After collection, clams will be maintained in a holding tank with unfiltered flow through seawater at the Cal Poly pier at 15±1°C. Individuals will be allowed to acclimate for at least two weeks before spawning experiments, but since spawning generally occurs in late summer to fall (Coe 1947, Alvarado-Alvarez et al. 1996), some may be acclimated for many months. We will induce spawning by exposing clams to macerated gonads (Strathman 1987) and/or following the methods of Alvarado-Alvarez et al. (1996) using serotonin to induce spawning. These two methods have shown the fastest response of spawning (Singh and Azam 2013). Experimental clams will be transported to the larval rearing lab on Cal Poly's main campus and placed in individual containers of 1.5 L of clean, filtered seawater for 1 h. To induce spawning, we will inject a solution of 0.4 ml of 5 m*M* serotonin in seawater buffered with 5 m*M* Tris-HCl (pH 8) directly into the gonad and/or we will add 10 ml of a slurry of macerated gonad to the containers with individual clams.

*Impacts of toxins on Pismo clam fertilization success and early development*

Treatments and fertilization: After spawning (generally ~30 min following injection/exposure to macerated gonad), gametes from each clam will be collected with a glass pipette and transferred to sterile beakers. We will observe eggs and sperm under a compound microscope to determine normal appearance (eggs) or motility (sperm), and we will discard abnormal gametes. Eggs from all clams spawned from a given source location will be washed in 0.2 µm filtered seawater using a 20 µm mesh screen and combined into a single beaker for fertilization. Sperm will be combined in a similar manner as eggs. To insure that our gamete concentrations are not limiting fertilization, we will conduct a series of preliminary fertilization experiments using serial dilution of sperm, with a target concentration that yields a 50% fertilization success rate. We will add 100-200 eggs in 1 ml of filtered seawater to each of 5 tubes with with 8 ml of filtered seawater. We will add 1 ml of a sperm solution to each egg tube, beginning with $10^6$ sperm per ml and diluting each subsequent tube of sperm 10 fold by adding 1 ml of the previous concentration to a clean tube with 9 ml of filtered seawater (Babcock and Keesing 1999, Baker and Tyler 2001). After 4 h, eggs will be fixed in formalin and examined under a dissecting microscope to estimate fertilization success rate.

After mixing, eggs will be divided into 1 L beakers with a solution of each toxin/concentration treatment in 0.2 µm filtered sea water or a control with filtered seawater only. Sperm will be added at the appropriate concentration as determined by the preliminary fertilization experiment.

Larval rearing: Fertilized eggs will be allowed to develop in larval rearing tanks incubated at 15±1°C. Larval rearing tanks will have an inner container suspended above the bottom of the larval rearing tank to allow influx of seawater from the larval rearing tank through the bottom of the container, but isolated with a 20µm bottom mesh to keep eggs inside each inner container. This allows for frequent water changes. A 50% water change will occur daily throughout the duration of the experiment. Larvae will be kept at a density of no more than 10 larvae/ml. Larvae will be fed *Isochrysis galbana* weekly.

Effect of toxins on different stages of development: Approximately 100 larvae from each treatment will be removed at various stages throughout development and placed in 25ml falcon tubes with 100 µL of buffered formalin to stop development and preserve larvae. We will assess arrested development at the following stages (times are approximate and based on the tropical congener *Tivela mactroides* [Reverol et al. 2004] so Pismo clam developmental times in colder waters are likely longer):

1. fertilization membrane (5 minutes)
2. first cleavage stage (1 hour)
3. blastula stage (3 hours)
4. gastrula stage (5 hours)
5. trocophore stage (10.5 hours)
6. straight-hinged veliger (14.5 hours)
7. umbo (veliger) (7.5 days)
8. pediveliger (22 days)

Percent of fertilized embryos and normally developing larvae will be determined by randomly observing 100 individuals from each tube (toxin/concentration treatment) under a Leica EZ4D dissecting microscope. Fertilization success, percent of malformed embryos and percent of abnormal larvae will be calculated for each treatment. Larval condition and survivorship data will be analyzed using generalized linear mixed effects models, including region (Southern vs Central) and human impact (more vs less urbanized) as fixed factors and site as a random factor.

## 10. RELATED RESEARCH:

Pismo clams are an iconic fishery species in California, and have a long history of exploitation and study. Some fishery data are available for most of the first half of the 20th century (Weymouth 1923, Fitch 1950, Wendell et al. 1986, Pattison and Lampson 2008), and researchers recognized that stocks were overexploited nearly 100 years ago (e.g. Weymouth 1923, Herrington 1929). The commercial fishery was closed in 1945 to protect the species (Pattison and Lampson 2008), but populations remain low in most of the state despite greatly reduced fishing pressure (Fig. 1, Pattison and Lampson 2008).

However, despite the long history of exploitation and the iconic status of the species, there have been few studies on Pismo clam biology and ecology over the last several decades. Miller et al. (1975) conducted surveys of Pismo clam diggers from Monterey to Newport Beach, and found high densities of clams outside of the sea otter foraging zone, and Stephenson (1974) investigated adult ecology, reproduction and recruitment in Monterey Bay. To our knowledge, there have been few statewide surveys of abundance and no follow up studies on recruitment in the field in any location since then. Other more recent work has spawned Pismo clams in the lab (Alvarado-Alvarez et al. 1996), but the emphasis of this work was on propagation through aquaculture. Until we began our statewide assessment study, there were only data on Pismo clam densities from a few locations and a few time periods.

There is also a rich literature on the levels of toxins in the tissues of bivalves as sentinel species (e.g. Fowler 1990, Lauenstein et al. 1998, Kimbrough et al. 2008, Dodder et al. 2014), and some work has examined these patterns in the genus *Tivela* (Jaffe et al. 1995), but fewer studies that have investigated the impacts of toxins on the development or survivorship of larvae (Beiras and His 1994, Alzieu 2000). No published work has sought to understand the impacts of toxins on the development or survivorship of Pismo clams. Furthermore, there are no studies attempting to understand the factors that have led to the decline of Pismo clams or the factors that have impeded their recovery (e.g. fishing, predation and pollution), nor how any of these factors vary regionally.

## 11. BUDGET RELATED INFORMATION:

### A. Budget Justification

*Personnel*

The salary rates are based on the California State University and Cal Poly Corporation established salary rate paid during the 2014-2015 Academic year (July 1 – June 30). The salary and wage rates for all employees include a projected 4.5% salary increase per year. The rates shown are for budgetary purposes; the actual rates in effect at the time the work is performed will be charged to the project.

A Research Associate, Grant Waltz, will contribute 5% effort, or 104 hours per year, to this project per year. Mr. Waltz will help coordinate and participate in some field collection activities.

This proposal requests that one undergraduate student assistant be supported for each year of this grant. For this student, this will include 100 hours to be worked during the academic year and summer, which will be paid at a rate of 12.00 per hour. This student will be responsible for maintaining spawning adults and larval cultures of Pismo clams at the CCMS Pier and on Cal Poly's main campus.

*Fringe Benefits & Employer Payroll Taxes*

Fringe benefits for Corporation staff are calculated at 56.8%, and include Workers Compensation, FICA, State Unemployment Insurance (SUI), and Medicare. Student benefits are estimated at 4.9% and include FICA (when applicable) as well as SUI and Workers Compensation, which is determined by the work the students are doing and the environment in which they do that work and their enrollment status. Rates in effect at the time the work is performed will be billed to the project.

*Domestic Travel*

A total of $2,000 is requested in year one to support the costs of the proposed field survey. These will enable the PIs, Research Associate and students, to travel to field sites in Central and Southern California for 20 days. This funding will support all costs associated with vehicles, lodging, and meals and incidentals.

A total of $1,650 is requested in year two to support conference travel costs. The PIs and graduate student will attend a regional marine ecology/conservation conference, location and timing TBD. This funding will support all costs associated with transportation, lodging, and meals and incidentals.

*Supplies & Materials*
A total of $18,952 has been requested in year 1 for project related supplies and materials. These supplies and materials will include culturing supplies ($7,500), holding tanks ($2,000), analysis of toxins ($7,500) and miscellaneous consumable field supplies ($1,952).

*Other Direct Costs*
A total of $20,000 ($10k per year) will pay for in-state tuition for a graduate student for two years. The student will have several responsibilities on this project, including co-leading and participating in all field activities, co-supervising undergraduates and being ultimately responsible for maintaining larval culturing experiments, executing lab studies on larvae, as well as assisting the PIs with data analysis and report/publication preparation.

*Indirect Costs*
Cal Poly State University's Federal negotiated indirect rate is 38.5% of modified total direct costs, effective July 1, 2015. Modified total direct costs exclude equipment, capital expenditures, participant support, charges for patient care, tuition remission, rental costs of off-site facilities, scholarships, and fellowships as well as that portion of each subgrant and subcontract in excess of $25,000.

**B. Matching Funds**

The Sponsor requires a minimum of 50% match on all requested funds. The matched funding for this proposal will be contributed as follows:

*In-Kind*
PI Benjamin Ruttenberg will contribute 13.34% assigned time to the project, which is equivalent to 1.2 academic year months. Costs for his time are calculated at his normal academic salary rate. Fringe benefits associated with assigned time are calculated at 48.03%, and can include the following: FICA, State Unemployment Insurance, Worker's Compensation, non-industrial leave, health and life insurance benefits, and retirement benefits (PERS).

*Cash Match*
The City of Pismo Beach has provided $15,000 cash match to cover salary support for PI, Lisa Needles. This funding will cover the costs of approximately 86 hours per year, and associated fringe benefits. Fringe benefits for Corporation staff are calculated at 56.8%, and include Workers Compensation, FICA, State Unemployment Insurance (SUI), and Medicare.

## 12. ANTICIPATED BENEFITS:

This study will provide the first data on the distribution of toxins in Pismo clams and the impact of these toxins on larval development and survivorship. The primary users of our results will be the CDFW and other state agencies (e.g. State Parks) charged with managing Pismo clam populations. While CDFW's Marine Region has adopted a policy to not write letters of support for any proposal, staff have indicated that they would like to be involved in this project, particularly as these data may inform stock assessments (P. Kalvass, pers. comm.). In addition, we anticipate that a variety of municipalities, particularly the Cities of Pismo Beach and Morro Bay, as well as other state, regional, and local water boards will use our results in policymaking (see letters of support). We also expect federal agencies, such as NOAA's National Marine Sanctuaries, the National Park Service and the Bureau of Ocean Energy Management, to use the this information in their management decisions as well as for outreach (see letters of support).

This information will allow us to evaluate the relative importance of toxins on the replenishment of populations, and will shed new light on one of the factors that may be impeding Pismo clam recovery throughout the state. When combined with data from our ongoing assessment program, our information will help guide regional and site specific management strategies and restoration by helping identify locations and activities were restoration will be more likely—and less likely—to succeed.

## 13. COMMUNICATION OF RESULTS:

We will provide copies of all of our peer-reviewed and other publications and all data to all relevant agencies, organizations, and non-profits via our growing list of contacts for this project, many of whom have written letters of support for this project. These include CDFW, California State Parks, Central Coast Regional Water Quality Control Board, the Cities of Pismo Beach and Morro Bay, U.S. National Park Service, NOAA's National Marine Sanctuaries, BOEM, Central Coast Salmon Enhancement, and others. Furthermore, we will host workshops and meetings through the San Luis Obispo Science and Ecosystem Alliance, an integrated group of scientists, resource managers and stakeholders studying, supporting, and managing marine resources on the California Central Coast. This group is a particularly effective venue for sharing information because of the wide range of participating organizations, including many of the partner organizations listed above as well as other non-profits and commercial fishing and aquaculture organizations. We will also give presentations and briefings at local municipal management meetings (e.g. Pismo Beach city council meetings) as well as outreach presentations to the public (e.g. Santa Barbara Sea Center, San Simeon Coastal Discovery Center, San Luis Obispo "Science After Dark" public seminar series, presentations on local radio shows). We will also coordinate with Dr. Jennifer O'Leary, the Sea Grant Extension Specialist based at Cal Poly and Cal Poly's Office of Public Affairs on these and other media and social media outreach activities. Finally, undergraduate and Graduate students involved in this research will give talks at local and regional scientific conferences (e.g. Cal Poly Undergraduate Research Conference, Western Society of Naturalists) to advance their professional training and preparation.

## 14. REFERENCES:


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Dodder, N. G., K. A. Maruya, P. L. Ferguson, R. Grace, S. Klosterhaus, M. J. La Guardia, and J. Ramirez. 2014. Occurrence of contaminants of emerging concern in mussels (*Mytilus spp*.)

along the California coast and the influence of land use, storm water discharge, and treated wastewater effluent. Marine Pollution Bulletin 81: 340-346.

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Fukuyama, A. K., G. Shigenaka and R. Z. Hoff. 2000. Effects of residual Exxon Valdez oil on intertidal *Protothaca staminea*: mortality, growth, and bioaccumulation of hydrocarbons in transplanted clams. Marine Pollution Bulletin 40: 1042-1050.

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# PROJECTED WORK SCHEDULE

Recovery of the Pismo clam (*Tivela stultorum*) in California: the importance of pollution

| Activities | 2016-2017 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | M | A | M | J | J | A | S | O | N | D | J |
| Initial field collection of Pismo clam adults and recruits for toxin analysis | | | | | | | | | | | | |
| Sample preparation and toxin analyses | | | | | | | | | | | | |
| Data analyses for field toxin data and prep for year 1 larval rearing experiments | | | | | | | | | | | | |
| Field collections of Pismo clam adults for year 1 larval rearing experiments | | | | | | | | | | | | |
| Year 1 larval rearing experiments | | | | | | | | | | | | |
| Data analyses for year 1 larval rearing experiments | | | | | | | | | | | | |

| Activities | 2017-2018 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | M | A | M | J | J | A | S | O | N | D | J |
| Data analyses for year 1 larval rearing experiments | | | | | | | | | | | | |
| Field collections of Pismo clam adults for year 2 larval rearing experiments | | | | | | | | | | | | |
| Prep for year 2 larval rearing experiments | | | | | | | | | | | | |
| Year 2 larval rearing experiments | | | | | | | | | | | | |
| Data analyses for year 2 larval rearing experiments | | | | | | | | | | | | |
| Report preparation/ writing and ongoing scientific and outreach presentations | | | | | | | | | | | | |

**Year 1: 2/1/2016 - 1/31/2017**

OMB Control No. 0648-0362
Expiration Date 1/31/2018

## SEA GRANT BUDGET FORM 90-4

| GRANTEE: Cal Poly Corporation | | | GRANT/PROJECT NO.: | |
|---|---|---|---|---|
| BRIEF TITLE: Recovery of the Pismo clam (Tivela stultorum) in California: the importance of pollution | | | DURATION (months): 2/1/16 - 1/31/18 (24 months) | |
| PRINCIPAL INVESTIGATOR: Benjamin Ruttenberg & Lisa Needles | | | 12 months | 1 Yr. |
| **A. SALARIES AND WAGES:** | man-months | | | |
| 1. Senior Personnel | No. of People | Amount of Effort | Sea Grant Funds | Matching Funds |
| a. (Co) Principal Investigator: | | | | |
| Benjamin Ruttenberg | 1 | 1.2 | $0 | $10,165 |
| Lisa Needles | 1 | 0.5 | $0 | $4,678 |
| b. Associates (Faculty or Staff): | 0 | - | $0 | $0 |
| Sub Total: | 2 | 1.7 | $0 | $14,843 |
| 2. Other Personnel | | | | |
| a. Professionals: | 0 | - | $0 | $0 |
| b. Research Associates: | 1 | 0.6 | $2,299 | $0 |
| c. Res. Asst./Grad Students: | 0 | - | $0 | $0 |
| d. Prof. School Students: | 0 | - | $0 | $0 |
| e. Pre-Bachelor Student(s): | 1 | 0.9 | $1,200 | $0 |
| f. Secretarial-Clerical: | 0 | - | $0 | $0 |
| g. Technicians: | 0 | - | $0 | $0 |
| h. Other: GRADUATE TRAINEE | 1 | 4.5 | $0 | $0 |
| Total Salaries and Wages: | 5 | 7.7 | $3,499 | $14,843 |
| | | | | |
| **B. FRINGE BENEFITS:** | | **varied** | $1,365 | $7,539 |
| **Total Personnel (A and B):** | | | $4,864 | $22,382 |
| | | | | |
| **C. PERMANENT EQUIPMENT:** | | | $0 | $0 |
| | | | | |
| **D. EXPENDABLE SUPPLIES AND EQUIPMENT:** | | | $18,952 | $0 |
| | | | | |
| **E. TRAVEL:** | | | | |
| 1. Domestic | | | $2,000 | $0 |
| 2. International | | | $0 | $0 |
| **Total Travel:** | | | $2,000 | $0 |
| | | | | |
| **F. PUBLICATION AND DOCUMENTATION COSTS:** | | | $0 | $0 |
| | | | | |
| **G. OTHER COSTS:** | | | | |
| 1. Tuition Remission | | | $10,000 | $0 |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| **Total Other Costs:** | | | $10,000 | $0 |
| | | | | |
| **TOTAL DIRECT COST (A through G):** | | | $35,816 | $22,382 |
| | | | | |
| **INDIRECT COST (On campus 38.5% ):** | | | $9,939 | $8,617 |
| **INDIRECT COST (Off campus % of $ ):** | | | | |
| **Total Indirect Cost:** | | | $9,939 | $8,617 |
| | | | | |
| **TOTAL COSTS:** | | | $45,755 | $30,999 |

**Year 2: 2/1/2017 - 1/31/2018**

OMB Control No. 0648-0362
Expiration Date 1/31/2018

## SEA GRANT BUDGET FORM 90-4

| GRANTEE: Cal Poly Corporation | | | GRANT/PROJECT NO.: | |
|---|---|---|---|---|
| BRIEF TITLE: Recovery of the Pismo clam (Tivela stultorum) in California: the importance of pollution | | | DURATION (months): 2/1/16 - 1/31/18 (24 months) | |
| PRINCIPAL INVESTIGATOR: Benjamin Ruttenberg & Lisa Needles | | | 12 months | 1 Yr. |
| **A. SALARIES AND WAGES:** | man-months | | | |
| 1. Senior Personnel | No. of People | Amount of Effort | Sea Grant Funds | Matching Funds |
| a. (Co) Principal Investigator: | | | | |
| Benjamin Ruttenberg | 1 | 1.2 | $0 | $10,622 |
| Lisa Needles | 1 | 0.5 | $0 | $4,889 |
| b. Associates (Faculty or Staff): | 0 | - | $0 | $0 |
| Sub Total: | 2 | 1.7 | $0 | $15,511 |
| 2. Other Personnel | | | | |
| a. Professionals: | 0 | - | $0 | $0 |
| b. Research Associates: | 1 | 0.6 | $2,402 | $0 |
| c. Res. Asst./Grad Students: | 0 | - | $0 | $0 |
| d. Prof. School Students: | 0 | - | $0 | $0 |
| e. Pre-Bachelor Student(s): | 1 | 0.9 | $1,200 | $0 |
| f. Secretarial-Clerical: | 0 | - | $0 | $0 |
| g. Technicians: | 0 | - | $0 | $0 |
| h. Other: GRADUATE TRAINEE | 1 | 4.5 | $0 | $0 |
| Total Salaries and Wages: | 5 | 7.7 | $3,602 | $15,511 |
| | | | | |
| **B. FRINGE BENEFITS:** | | **varied** | $1,423 | $7,878 |
| **Total Personnel (A and B):** | | | $5,025 | $23,389 |
| | | | | |
| **C. PERMANENT EQUIPMENT:** | | | $0 | $0 |
| | | | | |
| **D. EXPENDABLE SUPPLIES AND EQUIPMENT:** | | | $0 | $0 |
| | | | | |
| **E. TRAVEL:** | | | | |
| 1. Domestic | | | $1,650 | $0 |
| 2. International | | | $0 | $0 |
| **Total Travel:** | | | $1,650 | $0 |
| | | | | |
| **F. PUBLICATION AND DOCUMENTATION COSTS:** | | | $0 | $0 |
| | | | | |
| **G. OTHER COSTS:** | | | | |
| 1. Tuition Remission | | | $10,000 | $0 |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| **Total Other Costs:** | | | $10,000 | $0 |
| | | | | |
| **TOTAL DIRECT COST (A through G):** | | | $16,675 | $23,389 |
| | | | | |
| **INDIRECT COST (On campus 38.5% ):** | | | $2,570 | $9,005 |
| **INDIRECT COST (Off campus % of $ ):** | | | | |
| **Total Indirect Cost:** | | | $2,570 | $9,005 |
| | | | | |
| **TOTAL COSTS:** | | | $19,245 | $32,394 |

June 2015

# BRIEF CURRICULUM VITAE

(Needed for all Principal and Associate Investigators)

**NAME** Benjamin Ruttenberg

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## EDUCATION

Department of Ecology, Evolution and Marine Biology, UCSB, Ph.D., 2006
Thesis: *Causes and consequences of geographical variation in demography and larval exchange in reef fishes*

School of Forestry and Environmental Studies, Yale University, M.S., 1999
Thesis: *The effects of artisanal fishing on marine communities in the Galápagos Islands*

Tufts University, B.A., 1997

## POSITIONS HELD

| | |
|---|---|
| 2013-present | Assistant Professor, Biological Sciences Department, Cal Poly |
| 2009-2013 | Research Fishery Biology, NOAA Fisheries Southeast Fisheries Science Center |
| 2008-2009 | Marine Ecologist, U.S. National Park Service |
| 2007-2008 | Postdoctoral Fellow, Scripps Institution of Oceanography/UCSD |
| 2006-2007 | UC-MEXUS Postdoctoral Fellow and Science of Marine Reserves in Latin America Project Manager, Universidad Autónoma de Baja California |

## SELECTED PUBLICATIONS


1. Adam, T. C., D. E. Burkepile, B. I. Ruttenberg, and M. J. Paddack. 2015. Herbivory and the resilience of Caribbean coral reefs: knowledge gaps and implications for management. Marine Ecology Progress Series 520: 1-20.

2. Ruttenberg, B. I. and S. E. Lester. 2015. "Patterns and processes in geographic range size in coral reef fishes." In *Ecology of Fishes on Coral Reefs*. C. Mora ed. Academic Press, pp. 97-103.

3. Ruttenberg, B. I., S. L. Hamilton, S. M. Walsh, M. K. Donovan, A. Freidlander, E. DeMartini, E. Sala, and S. A. Sandin. 2011. Demographic shifts in coral reef fish communities across a gradient of human disturbance. PLoS One 6(6): e21062.

4. Ruttenberg, B. I., S. L. Hamilton, and R. R. Warner. 2008. Spatial and temporal variation in the natal otolith chemistry in a Hawaiian reef fish: prospects for measuring population connectivity. Canadian Journal of Fisheries and Aquatic Sciences 65: 1181-1192.

5. Ruttenberg, B. I. and R. R. Warner. 2006. Spatial variation in the chemical composition of natal otoliths from a reef fish in the Galápagos Islands. Marine Ecology Progress Series 328: 225-236.

6. Ruttenberg, B. I., A. J. Haupt, A. I. Chiriboga, and R. R. Warner. 2005. Patterns, causes and consequences of regional ecological variation in a reef fish. Oecologia 145: 394-403.

7. Lester, S. E., B. S. Halpern, K. Grorud-Colvert, J. Lubchenco, B. I. Ruttenberg, S. D. Gaines, S. Airamé, and R. R. Warner. 2009. Biological effects within no-take marine reserves: a global synthesis. Marine Ecology Progress Series 384: 33-46.

8. Ruttenberg, B. I. and E. F. Granek. 2011. Bridging the marine-terrestrial disconnect in coastal zone science and management. Marine Ecology Progress Series 434:203-212.

9. Lester, S. E., B. I. Ruttenberg, S. D. Gaines, and B. P. Kinlan. 2007. The relationship between dispersal ability and geographic range size. Ecology Letters 10: 745-758.

10. Ruttenberg, B. I., P. J. Schofield, J. L. Akins, A. Acosta, M. W. Feeley, J. Blondeau, S. G. Smith and J. S. Ault. 2012. Rapid invasion of Indo Pacific lionfishes (*Pterois volitans* and *Pterois miles*) in the Florida Keys, USA: evidence from multiple pre- and post-invasion datasets. Bulletin of Marine Science. 88: 1051-1059.

June 2015

# BRIEF CURRICULUM VITAE

(Needed for all Principal and Associate Investigators)

**NAME** Lisa Needles

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## EDUCATION

University of California Davis, Zoology, B.S., 1990

Oregon State University, Science and Mathematics Education, M.A.T., 1997

California Polytechnic State University, Biological Sciences, M.S., 2007

University of California Santa Barbara, Ecology, Evolution and Marine Biology, Ph.D., 2013

## POSITIONS HELD

2012-present Part-time Faculty, California Polytechnic State University

2003-present Research Associate, Center for Coastal Marine Sciences

## SELECTED PUBLICATIONS

- **Needles, LA,** S Gosnell, GT Waltz, DE Wendt, and SD Gaines (2015). Trophic cascades in a novel ecosystem: Native apex predators facilitate a dominant invader in an estuarine community. *Oikos.* doi: 10.1111/oik.01865.

- **Needles, LA**, SE Lester, R Ambrose, A Andren, M Beyeler, M Connor, J Eckman, B Costa-Pierce, SD Gaines, K Lafferty, H Lenihan, J Parrish, MS Peterson, A Scaroni, J Weis, DE Wendt (2015). Managing bay and estuarine ecosystems for multiple services. *Estuaries and Coasts* 38(1): 35-48.

- **Needles, LA** and DE Wendt (2013). Big changes to a small bay: Introduced species and long-term compositional shifts to the fouling community of Morro Bay (CA). *Biological Invasions* 15(6): 1231-1251.

- Woodson CB, DI Eerkes-Medrano, A Flores-Morales, Foley MM, SK Henkel, M Hessing-Lewis, D Jacinto, **LA Needles,** MT Nishizaki, J O'Leary, CE Ostrander, M Pespeni, KB Schwager, JA Tyburczy, KA Weersing, AR Kirincich, JA Barth, MA McManus, L Washburn (2007). Local diurnal upwelling driven by sea breezes in northern Monterey Bay. *Continental Shelf Research* 27:2289-2302

June 2015

# BRIEF CURRICULUM VITAE

(Needed for all Principal and Associate Investigators)

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## EDUCATION

California Polytechnic State Univ. San Luis Obispo, Biology, *Magna Cum Laude,* B.S. 1993
Harvard University, Biology, A.M. 1996
Harvard University, Biology, Ph.D. 1999
University of Hawaii, Manoa, Marine Biology, 1999-2000

## POSITIONS HELD

Dean of Research, California Polytechnic State University, 2014-present
Interim Dean of Research, California Polytechnic State University, 2013-14
Director, Center for Coastal Marine Sciences, California Polytechnic State University, 2012-present
Associate Dean, College of Science and Math, California Polytechnic State University, 2010-14
Professor of Biology California Polytechnic State University, San Luis Obispo, 2010-present
Associate Professor of Biology, California Polytechnic State University, San Luis Obispo, 2006-10
Assistant Professor of Biology, California Polytechnic State University, San Luis Obispo, 2002-06
Assistant Professor of Biology, The University of North Carolina at Greensboro 2000-02

## SELECTED PUBLICATIONS

Starr, R.M., Wendt, D.E., Barnes, C.L., Marks, C.I., Malone, D., Waltz, G., Schmidt, K.T., Chiu, J., Launer, A.L., Hall, N.C., and Yochum, N. (2015). Variation in Responses of Fishes across Multiple Reserves within a Network of Marine Protected Areas in Temperate Waters. *PLoS ONE* 10(3): e0118502. doi:10.1371.

Needles, L. A., Gosnell, J. S., Waltz, G. T., Wendt, D. E. and Gaines, S. D. 2015. Trophic cascades in an invaded ecosystem: native keystone predators facilitate a dominant invader in an estuarine community. – Oikos doi: 10.1111/oik.01865

Kimura, S., G.T. Waltz, J.R. Steinbeck, and D.E. Wendt (2014) A comprehensive approach for understanding the impacts of visitation to temporally variable ecological systems. *Ocean and Coastal Management,* 95:241-253.

Needles, L.A. and D.E. Wendt (2013) "Big changes to a small bay: Introduced species and long-term compositional shifts to the fouling community of Morro Bay (CA). *Biological Invasions* 15:1231-1251

Mireles, C., R. Nakamura, and D.E. Wendt (2012) A collaborative approach to investigate site fidelity, home range, and homing behavior of cabezon (*Scorpaenichthys marmoratus*). *Fisheries Research* 113:133-142.

Yochum, N., R.M. Starr and D.E. Wendt (2011) Utilizing fishermen knowledge and expertise: Keys to success for collaborative fisheries research. *Fisheries* 36: 593-605.

Caselle, J.E., J.R. Wilson, M.H. Carr, D.P. Malone, and D. E. Wendt (2010) Can we predict interannual and regional variation in delivery of pelagic juveniles to nearshore populations of rockfishes (genus Sebastes) using simple proxies of ocean conditions? *CalCOFI Reports* 51:91-105.

Wendt, D.E. and R.M. Starr (2009) Collaborative Research: An Effective Way to Collect Data for Stock Assessments and Evaluate Marine Protected Areas in California. Marine and Coastal Fisheries: Management, Dynamics, and Ecosystem Science. 1: 315-324.

Wendt, D.E, L. Pendleton and D.L. Maruska (2009) "Morro Bay, California: A case study of ecosystem-based management through community action" In: K. L. McLeod and H. M. Leslie (editors). Ecosystem-Based Management for the Oceans. Island Press.

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**RESOLUTION NO. R-2015-054**

**A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF PISMO BEACH TRANSFERRING $15,000 FROM VARIOUS GENERAL FUND ACCOUNTS TO THE SEA GRANT PROJECT ACCOUNT, TO BE USED AS MATCHING FUNDS FOR A PISMO CLAM STUDY GRANT, AND AUTHORIZING THE CITY MANAGER TO EXECUTE AN ASSOCIATED MEMORANDUM OF UNDERSTANDING (MOU) WITH CALIFORNIA POLYTECHNIC STATE UNIVERSITY, SAN LUIS OBISPO**

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**WHEREAS**, the City of Pismo Beach wishes to support research to increase the Pismo clam population; and,

**WHEREAS,** representatives of Cal Poly are seeking a Sea Grant for a Pismo clam study, which grant application requires a grant matching contribution; and,

**WHEREAS,** the grant applicants are in need of $15,000 in additional grant matching funds; and,

**WHEREAS,** the General Fund Budget for Fiscal Year 2015, in various accounts, has a combined balance of $15,000 available to cover the remaining Sea Grant match funding requirement.

**NOW, THEREFORE, BE IT RESOLVED** by the City Council of the City of Pismo Beach that:

1. Funds in the amount of $5,000 be transferred from each of the following General Fund accounts: Council Contingency Fund; Conference and Visitors Bureau (CVB) Contributions; and Clam Study, to a Sea Grant Project account, for a $15,000 total Pismo clam study grant matching contribution;

2. Said funds shall be released upon award of the Sea Grant to the applicants; and

3. The City Manager is hereby authorized to execute an associated Memorandum of Understanding (MOU) with California Polytechnic State University, San Luis Obispo, as needed to release City funding in the event the grant is awarded.

**UPON MOTION OF** Mayor Pro Tem Waage, seconded by Council Member Blake, the foregoing resolution was adopted by the City Council of the City of Pismo Beach this 16th day of June 2015, by the following vote:

| | | |
|---|---|---|
| **AYES:** | **5** | **Council Members Waage, Blake, Howell, Reiss, Higginbotham** |
| **NOES:** | **0** | |
| **ABSENT:** | **0** | |
| **ABSTAIN:** | **0** | |
| **RECUSED:** | **0** | |

**Approved:**

**Shelly Higginbotham**
**Mayor**

**Attest:**

**Erica Inderlied**
**Interim City Clerk**

# SUMMARY PROPOSAL FORM

**PROJECT TITLE:**

RECOVERY OF THE PISMO CLAM (TIVELA STULTORUM) IN CALIFORNIA: THE IMPORTANCE OF POLLUTION

**OBJECTIVE:**

Our main objectives are twofold: 1) evaluate the levels of toxins present in Pismo clam adults and recruits in more urbanized and less urbanized areas of California, and 2) determine the impacts of environmentally relevant levels of these toxins on development and survivorship of Pismo clam larvae. Answers to these questions will help us understand the impact of pollution as a limiting factor of Pismo clam populations. Results from this study, combined with other data we are collecting on abundance, size structure, and other potential limiting factors, will help us suggest and evaluate management strategies and restoration activities that are most likely to be successful in increasing Pismo clam abundance.

**METHODOLOGY:**

Our methods follow our objectives. To evaluate levels of toxins in adult and recruit Pismo clams, we will make collections of individual clams from beaches in more urbanized and less urbanized areas of Southern and Central California. Tissue will be dissected and homogenized, and analyzed for a suite of environmental toxins, including pesticides, herbicides, endocrine disrupters, and hydrocarbons. To measure the impact of toxins on development and survivorship of Pismo clam larvae, we will spawn clams and grow the larvae in varying concentrations of the important toxins identified by objective 1. We will use standard larval assays to measure larval developmental rate, developmental abnormalities, and survivorship.

**RATIONALE:**

The Pismo clam (*Tivela stultorum*) once supported a thriving commercial and recreational fishery in California, but abundance has declined dramatically throughout California in recent decades. While some populations appear stable, others remain small despite limited human take for many years. Conventional wisdom suggests that sea otters limit Pismo clam abundance where otters are present, but aside from a few high density sites outside of the otters' range (i.e., below Pt Conception), abundance across the state is still low. The other factors that limit Pismo clam recovery are presently unknown, but anthropogenic pollutants may be one of these factors. Pismo clams' preferred habitats are the lower intertidal and shallow subtidal of sandy beaches; in these habitats, they are exposed to elevated levels of many toxins, especially in areas near urban centers. Like many marine invertebrates, the larvae of Pismo clams may be particularly vulnerable to pollutants, a vulnerability that may limit larval supply, recruitment, and ultimately adult population sizes. We seek to understand the relative importance of pollution as a limiting factors on the recovery of Pismo clam as a step towards developing successful management and restorations strategies.

University of Southern California
Sea Grant Program
Los Angeles, CA 90089

June 29, 2015

To the USC Sea Grant Evaluation Committee:

On behalf of the Bureau of Ocean and Energy Management (BOEM), Pacific Region, I would like to express our support for the Cal Poly proposal to USC Seagrant entitled "Recovery of the Pismo clam (*Tivela stultorum*) in California: the importance of pollution." The Bureau of Ocean Energy Management (BOEM) has a great interest in understanding the impacts of resource extraction and any potential environmental impacts these resources may have, as well as a general interest in environmental conditions in marine systems more broadly. While BOEM only has jurisdiction in federal waters, potential environmental impacts from oil and gas operations may occur in state waters, as evidenced by the recent ruptured oil pipeline near Refugio State Beach in the Santa Barbara Channel. Such events can be devastating to populations of inshore species such as Pismo clams.

Species such as Pismo clams can be important indicators of inshore environmental quality, and Pismo clams are also of great interest as a fishery species. The data collected as part of this project will provide the first information on the potential impacts of environmental pollutants on populations of this important species. BOEM will also be able to use the data collected as part of this project to help evaluate the feasibility of future offshore energy projects.

I urge you to make this investment that will provide valuable information to a range of federal, state, and local partners, of which BOEM is only one.

Please do not hesitate to contact me if you require further information.

Warm regards,

Donna M Schroeder

Donna Schroeder, Senior Marine Ecologist
Bureau of Ocean Energy Management, Pacific Region
760 Paseo Camarillo, Suite 102
Camarillo, CA 93010
donna.schroeder@boem.gov
Voicemail: 805-384-6382

# Central Coast Salmon Enhancement, Inc.

229 Stanley Avenue, Arroyo Grande, CA 93420
Phone: (805) 473-8221 Fax: (805) 473-8167
www.centralcoastsalmon.com


June 25, 2015

Dr. Linda Duguay
Director
USC SeaGrant Program
Los Angeles, CA 90089

Dear Dr. Duguay:

Please accept our strong support for the SeaGrant proposal "Recovery of the Pismo clam (*Tivela stultorum*) in California: the importance of pollution," submitted by Cal Poly. At Central Coast Salmon Enhancement, we seek to ensure that our natural resources continue to support the ecological, recreational, and economic needs of our community, with an emphasis on watershed and coastal ecosystems of the California Central Coast.

Historically, Pismo clams were an important part of both sandy beach ecosystems as well as recreational fisheries in the area. However, in recent years, their abundance has declined rapidly. Unfortunately, we do not know the causes of this decline, complicating management of the species. The proposed project will collect valuable data on the effects of toxins on Pismo clams, providing key information on one factor that may be limiting recovery.

Furthermore, the broader project has excellent potential for education and outreach to local communities; Pismo clams are important to the local economy and culture of the Central Coast, and as such they fit extremely well within the mission of Central Coast Salmon Enhancement.

I strongly urge you to support this important research, and I welcome any questions you may have.

Sincerely yours,

Christopher Lim
Executive Director

# United States Department of the Interior

NATIONAL PARK SERVICE
Channel Islands National Park
1901 Spinnaker Drive
Ventura, California 93001-4354

IN REPLY REFER TO:

1.A.2 (N2219) – CHIS

June 29, 2015

Dr. Linda Duguay
Director, University of Southern California Seagrant Program
Los Angeles, CA 90089

Dear Dr. Duguay:

I write to you to express my strong support for the Cal Poly Center for Coastal and Marine Sciences proposal to your agency, "Recovery of the Pismo clam (Tivela stultorum) in California: the importance of pollution." The National Park Service (NPS) is charged with maintaining the resources within National Park unimpaired for future generations. To achieve this mission, the Channel Islands National Park conducts ongoing monitoring of key species and habitats in the terrestrial and marine environments within Park boundaries.

Currently we know of two small but persistent Pismo clam populations within the park and one of these we attempt to survey every year. While not as abundant and as widespread as on the mainland, this species is iconic and was important pre-European contact as observed by Pismo clam shells in many of the middens at the Islands. In addition there continues to be a small amount of recreational harvest at the Islands. The park has no funds to monitor Pismo clam populations but has attempted to do a small amount of this time permitting on Santa Rosa Island.

We are in support of the proposed study for several reasons. It is unclear if the two Pismo clam populations within the park are self-sustaining or if they rely on outside sources of larvae from the mainland. While this study does not address this particular question of connectivity, the information garnered from it will have direct relevance as there is relatively little known about this species. More importantly, the clam populations at the Channel Islands are free from many of the threats facing mainland populations, including urban runoff and other pollution. The clam populations at the Islands should prove to be the best control available for any kind of pollution studies. Mussels are often collected at the Islands for similar comparisons and this study should be complimentary to that information.

This project will provide critical information on an iconic but understudied and declining species in the region. These data will help the Park Service understand the status of and threats to Pismo clams in a regional context.

I urge you to support this important research proposal. Please do not hesitate to contact me if you require additional information.

Sincerely,

Russell Galipeau
Superintendent

**UNITED STATES DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
NATIONAL OCEAN SERVICE
**Channel Islands National Marine Sanctuary**
University of California Santa Barbara
Ocean Science Education Building 514
Santa Barbara, CA 93106

July 2, 2015

Dr. Linda Duguay
Director, University of Southern California Seagrant Program
Los Angeles, CA 90089

Dear Dr. Duguay:

This letter expresses my strong support for the Cal Poly SeaGrant submission "Recovery of the Pismo clam (Tivelastultorum) in California: the importance of pollution." Our agency is responsible for managing National Marine Sanctuaries, fisheries in federal waters, and federally-listed marine species throughout the country. To execute this mission, we often partner with universities and other research organizations, as well as state partners for species that occur in state waters, to provide the data necessary to take appropriate management actions. Along the central and southern California coast, there is a critical need for information to address issues relevant to all of these topics. National Marine Sanctuaries exist in the Santa Barbara Channel to the south and from Monterey Bay south to Cambria to the north, and Pismo clams are found throughout this region, albeit in much smaller numbers than in decades past.

While Pismo clams generally occur in state waters, they were once abundant in the coastal areas of the Monterey Bay National Marine Sanctuary and anecdotal evidence suggests that there are populations inside the Channel Islands National Marine Sanctuary. Understanding the causes of decline—and potential for recovery—of all species inside of National Marine Sanctuary waters is one of the key missions of our agency. Understanding the impacts of pollutants on these species is particularly important since National Marine Sanctuary legislation expressly prohibits dumping of these pollutants inside of Sanctuary waters. However, pollutants may still find their way into Sanctuary waters, as evidenced by the projected trajectory of oil from the Refugio Oil Spill in May.

While not part of the main research plan, our office will also provide transport to the Channel Islands for Cal Poly researchers to survey and sample island clam populations opportunistically if and when it is mutually convenient.

The information obtained from this project will give us a better understanding of one of the overlooked but still charismatic species in the California National Marine Sanctuaries. I hope you agree and will support this important research proposal.

Please contact me if you have any additional questions of me.

Sincerely,

Chris Caldow
Research Team Lead
Channel Islands National Marine Sanctuary
Email: chris.caldow@noaa.gov
Phone: 805-893-6419

**CITY OF MORRO BAY**
HARBOR DEPARTMENT
1275 Embarcadero Road
Morro Bay, CA 93442

June 24, 2015

Dr. Linda Duguay, Director
University of Southern California Sea Grant
3616 Trousdale Pkwy, AHF 253
Los Angeles, CA 90089-0373

RE: Support of Cal Poly San Luis Obispo's Center for Coastal Marine Sciences Grant Proposal for the Importance of Pollution on Pismo Clam Recovery

Dear Ms. Duduay,

As you may know, Morro Bay has numerous important commercial and recreational fisheries. In the not too distant past, Pismo clams played a large role San Luis Obispo County's tourism and recreational fisheries, and to a degree, in certain commercial applications. Unfortunately, due no doubt to numerous factors, Pismo clam populations regionally and elsewhere plummeted and appear to be at historic lows.

While there are small isolated pockets of Pismos along California's beaches, and large numbers of them along the Mexico's Baja peninsula, there has yet to be any significant Pismo resurgence along the majority of California's beaches. Given the historic abundance and importance of these not-well-known bivalves, any scientific work that might help to understand Pismos and bring them back to any significant degree of abundance is a laudable endeavor.

Therefore the City of Morro Bay lends its enthusiastic support to Cal Poly San Luis Obispo's Center for Coastal Marine Sciences California Sea Grant proposal "Recovery of the Pismo Clam (*Tivela stultorum*) in California: the Importance of Pollution." We hope that this project is favorably received by Sea Grant to enable this important research. Thank you for your consideration.

Sincerely,

Eric Endersby
Harbor Director

c: Lisa Needles, Ph.D., Cal Poly SLO Center for Coastal Marine Sciences

**From the Office of the Mayor**
Shelly Higginbotham
760 Mattie Road
Pismo Beach, CA 93449
(805) 235-6604

Dr. Linda Duguay, Director
University of Southern California Sea Grant
3616 Trousdale Pkwy, AHF 253
Los Angeles, CA 90089-0373

Dear Dr. Duguay,

I am writing to express the ardent support of the City of Pismo Beach for the Cal Poly proposal to USC Sea Grant entitled "Recovery of the Pismo clam (Tivela stultorum) in California: the importnace of pollution." Pismo clams were once abundant in Pismo Beach but they now declined to low levels not only in PIsmo Beach but also throughout San Luis Obispo County. The City of Pismo Beach is very interested in restoring the populations of Pismo clams as the clam is of recreational, historical, and economical importance to the City of Pismo Beach. The City of PIsmo Beach was once the center of recreational fishing of Pismo clams and the clams were so abundant in Pismo Beach that the clams were named after the city. Pismo Beach was once considered the clam capital of the world and the Pismo clam is deeply rooted in our identity even though the last legal sized clam was taken in 1993 and even smaller sized clams are very rare to find. Despite the decline in the Pismo clam population, Pismo clams remain the icon for the city of Pismo Beach and they continue to be a part of our cultural identity. We have hosted an annual clam festival for 69 years to honor the signifigance of the Pismo clam to our community and our quarterly newsletter The Clam Chronicle, is a tribute to the importance of the Pismo clam to our community.

The restoration of the Pismo clams would greatly benefit our community economically, culturally, and recreationally and therefore the City of PIsmo Beach strongly supports the proposal as a first step in understanding what is limiting clam populations. Restoration of the Pismo clam is so important to our city that the city council unanimously decided to commit $15,000 in matching funds toward this project. We hope that the USC Sea Grant will support this important work to restore an iconic species.

Please do not hesitate to contact me should you have any questions.

Sincerely,

Shelly Higginbotham

Shelly Higginbotham
Mayor

July 7, 2015

Dr. Linda Duguay, Director
USC SeaGrant Program
Los Angeles, CA 90089

Dear Dr. Duguay:

I write to express my strong support of the Cal Poly grant submission to USC Sea Grant titled: "Recovery of the Pismo clam (Tivela stultorum) in California: the importance of pollution." The proposal by the Cal Poly team supports the efforts of our agency to understand and monitor the impacts of pollutants in Calfornia's waters.

For many years I have been the lead staff scientist implementing the research and monitoring program in Central California for the Region 3 Water Quality Control Board. The proposed work compliments the work we do, especially as the research will be monitoring emerging pollutants in tissues of adult animals and investigating their impact on larval development and survival. It goes without saying that our agency has limited resources, and we do not have the ability to collect data on all of the species and pollutants we would wish to; for this reason a study like that proposed by Cal Poly is essential to helping our agency meet our research and monitoring goals.

Please contact me if you have additional questions. I can be reached at (805) 549-3333 or Karen.worcester@gmail.com.

Sincerely,

Karen R. Worcester
Senior Environmental Scientist, Central Coast Ambient Monitoring